RESTORATION OF ECOSYSTEM HEALTH IN SOUTHWESTERN FORESTS

Comprehensive Report
October 1, 1995 to September 30, 2000

Submitted to:
Bureau of Land Management, Arizona Strip District

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Ecological Restoration Institute
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Compiled by:
Amy Waltz, Peter Fulé, Greg Verkamp
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EXECUTIVE SUMMARY

The **Restoration of Ecosystem Health in Southwest Forests** project was initiated in 1995 to develop the scientific basis for ecological restoration of southwestern ponderosa pine forests. Fire exclusion, grazing and logging over the past 120+ years have caused contemporary southwestern forests to become dense with small trees and heavy fuels, at the expense of the diverse native plant community. Instead of the low intensity surface fires that burned frequently prior to Euro-American settlement, current fuel loads now support stand-replacing crown fires. These unnatural conditions are not sustainable, as evidenced by the increasing size and severity of forest fires. Extensive research suggests that active restoration is needed to regain natural ecological structure, composition, and function.

Jointly sponsored by the Bureau of Land Management (Arizona Strip District), Ecological Restoration Institute (Northern Arizona University) and the Arizona Game and Fish Department, the project sampled forests across the Southwest and relict stands in northern Mexico to establish a range of variability in forest types and past disturbance history. Contemporary disturbance by severe wildfires was also examined. The central focus of the project has been to establish experimental studies of ecological restoration treatments on BLM lands at Mt. Trumbull, Grand Canyon-Parashant National Monument, Arizona. These studies have been and will continue to be used to examine ecosystem responses, including plants, arthropods, birds and mammals, to ponderosa pine restoration treatments.

By 2000, restoration experiments include a replicated experimental block design of treated and control forests nested within an ecosystem-level landscape restoration at Mt. Trumbull, Arizona. Monitoring protocols are documented and standardized for comparison with other sites across the Southwest and elsewhere. A series of complementary studies at Mt. Trumbull and other sites addressed non-experimental questions, especially through retrospective dendroecological techniques.

Researchers continue to monitor forest and fuel conditions, as well as the response of arthropod, small mammal, and avian populations to restoration treatments. Data from both experimental and retrospective studies have been used to improve restoration treatments and techniques through the adaptive management process. Collaborative planning efforts for restoration of designated Wilderness are also underway. Five years marks only the beginning of the restoration process at Mt. Trumbull; the research is designed for long-term study with permanent monitoring systems and designated control areas.

This large, integrative project is developing into an intensive, comprehensive study of ecosystem restoration on a landscape scale. The Mt. Trumbull site has been featured in national restoration debates and has been the focus of intensive scrutiny by media and interest groups. Outreach has been extensive. To date, a total of 28 papers or posters have been presented at national meetings, and 33 papers have been published in symposia and peer reviewed journals.

*A lupine blue (*Plebejus icarioides*) basks on pusseytoe flowers(*Antennaria parviflora*) in a restored unit.*

INTRODUCTION

OVERVIEW

In 1995, the Bureau of Land Management - Arizona Strip District (BLM) and faculty from the Ecological Restoration Institute at Northern Arizona University (NAU) initiated the **Restoration of Ecosystem Health in Southwestern Forests** project. The Arizona Game and Fish Department (AGFD) became a sponsor and collaborator to the project in 1996, enhancing the wildlife research component. Changes in ponderosa pine forests due to Euro-American land management practices, including grazing, logging, and fire suppression, since *circa* 1870 have resulted in dense stands of pines with little or no understory across much of the Southwest. Most of these forests have not experienced fire for over 100 years, in striking contrast to the presettlement frequent surface fire regime. The subsequent increases in fuel build-up and tree densities have contributed to a higher susceptibility to severe fires that were not historically associated with these ecosystems. The five-year **Restoration of Ecosystem Health** project proposed three primary goals:

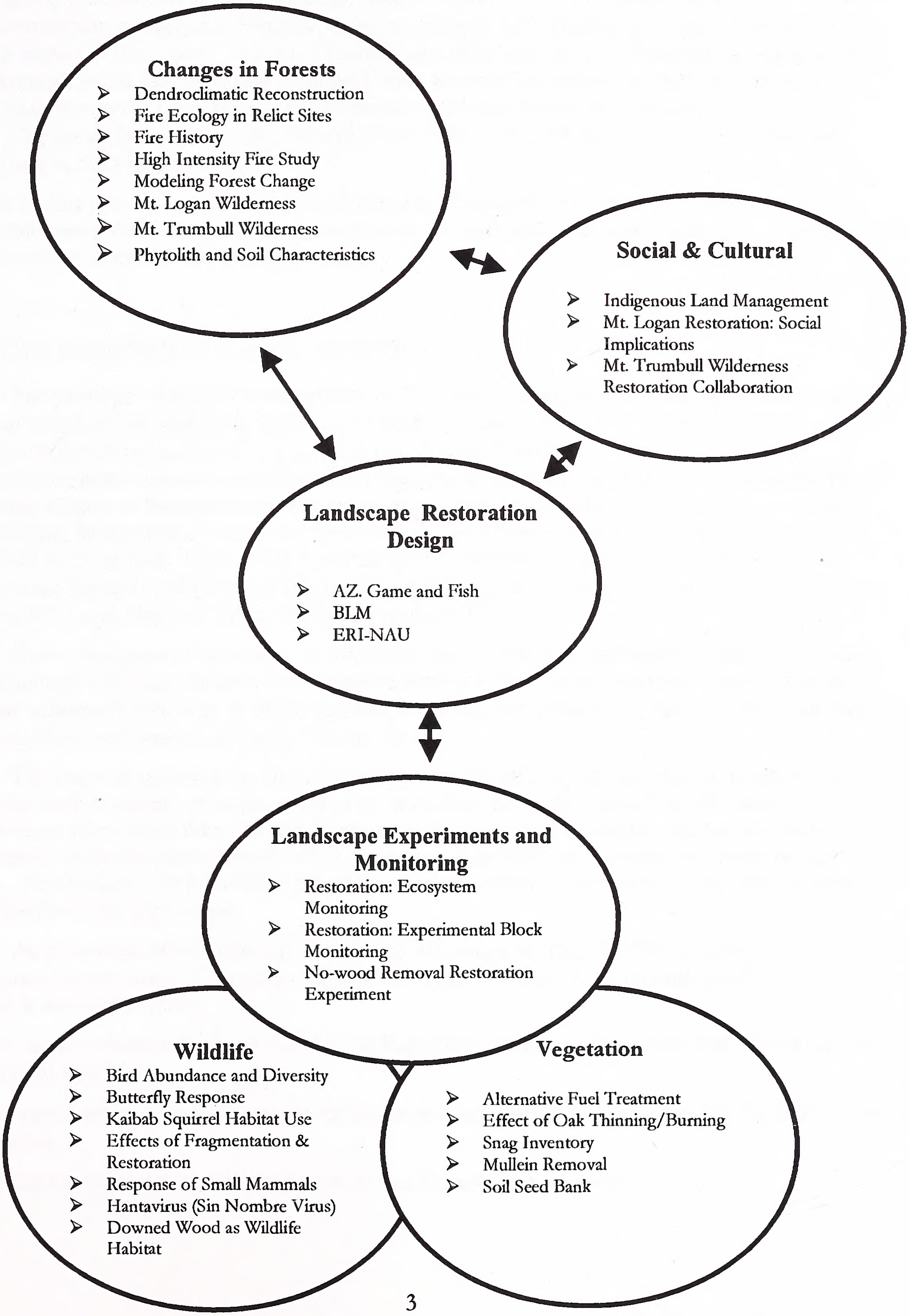
- Systematic analysis of the changes in southwestern forests since disruption of the natural regime of frequent, low-intensity fires.
- Comparison of the effects of disturbances such as intense wildfire to see if modern disturbed ecosystems can return to health.
- Initiation of carefully planned and monitored ecological restoration treatments in cooperation with land management agencies.

This document is the fifth annual report on the Restoration of Ecosystem Health project, summarizing the research carried out by the Ecological Restoration Institute and partners at Northern Arizona University. Complementary research by our collaborators, the Arizona Strip District BLM and Arizona Game and Fish, is summarized elsewhere. Since its inception, this project has received national attention as an object of both criticism and praise. The attention and careful review have contributed greatly to the successful implementation of restoration treatments in a landscape-level, operational setting incorporating scientific monitoring and assessment. This monitoring has then cycled back to revise and adjust the original treatment using adaptive management methodology.

Over the last five years, the project has generated a series of scientific studies. Figure 1 outlines the categories of studies, and the linkages between these components. The first goal above was met by sampling from a range of long-needled pine forest sites across the Southwest and a few isolated undisrupted sites in northern Mexico. These sites varied in land-use history, ranging from continuing frequent fire regimes to sites with fire exclusion beginning 50 to 130 years ago. The monitoring studies are summarized in the **Monitoring changes in southwestern forests** section. In addition, studies were initiated with Native American tribes, specifically the Kaibab Paiute band, to examine changes in traditional land use practices since Euro-American settlement and are summarized in the **Cultural studies and social implications** section. The studies in both of these categories have contributed to the development of landscape-level restoration experiments.

To address the second goal, we measured landscapes following high intensity, stand-replacing fires to assess ecosystem change. The *High Intensity Fire Study* is located within the **Monitoring changes in southwestern forests** section and also helped develop landscape restoration experiments.

Figure 1. Schematic diagram of research projects and restoration experiments described in this report. Related research projects carried out by the Bureau of Land Management and Arizona Game and Fish are reported elsewhere.



The final goal, experimental testing of restoration treatments, has been the most extensive, challenging, controversial, and productive component of the project. BLM, NAU, and AGFD worked together to initiate the first large-scale ecological restoration project in southwestern ponderosa pine forests at Mt. Trumbull on the Arizona Strip, Grand Canyon-Parashant National Monument. Shown by the overlapping categories in Figure 1, these experiments have generated the largest proportion of research studies in this report. Sections 3 (**Landscape level response**), 4 (**Vegetation response**) and 5 (**Arthropod, avian and mammal response**) describe scientific studies monitoring ecosystem responses to ponderosa pine restoration treatments which then feedback to landscape restoration design. The social and political consequences of restoration are addressed in section 2, **Cultural studies and social implications.**

Finally, this project has encouraged collaborative efforts with other agencies, public interest groups, land use groups and the general public. The last sections of the report detail this collaborative effort and some of the outreach it has generated.

ADAPTIVE RESEARCH AND MANAGEMENT

The paradigm of adaptive management is based on learning by doing, through monitoring the effects of initial actions and using these observations to refine and improve future prescriptions. Ecological restoration treatments in ponderosa pine forests of northern Arizona exemplify the adaptive management process, as changes have been made based on experience. The **Restoration of Ecosystem Health in Southwestern Forests** project is part of a broader context of studies in which the Ecological Restoration Institute and many partners have been drawing upon experience gained at the interval burning study sites (1975), Gus Pearson Natural Area (beginning 1992), Mt Trumbull (1995), Camp Navajo (1996), Grand Canyon National Park (1996), Southwest Forest Alliance/Forest Service (1997), and Flagstaff Urban/Wildland Interface (1998).

Goals of ecological restoration in ponderosa pine forests have remained consistent: recreate forest structural and compositional characteristics similar to those of the reference historical or pre-European settlement condition so that ecosystem processes, particularly frequent light underburning, can resume their sustainable, self-perpetuating patterns.

The focus on restoring the characteristics of the evolutionary environment of ponderosa pine forests has been frequently misinterpreted as an unvarying ecological "model" which leads to homogeneous forest conditions. In fact, however, restoration seeks to emulate the natural variability and diversity of southwestern forests, which have been simplified and degraded by recent human activity. Furthermore, the knowledge gained in early restoration experiments is being used to adapt and refine treatment approaches.

As restoration efforts intensify in northern Arizona, a number of different examples exist or are proposed on test areas. Currently, different examples in which the Ecological Restoration Institute is involved include:

- **Fire re-introduction/interval burning** studies (Chimney Spring, Limestone Flat, Grand Canyon National Park)
- **Full restoration** of presettlement forest structure (Gus Pearson Natural Area, Mt Trumbull, Camp Navajo)
- **Structural restoration without burning** (Gus Pearson Natural Area)

- **Minimal thinning** to safely re-introduce fire (Grand Canyon, Flagstaff Urban/Wildland Interface)
- **Intermediate thinning—2/4** replacement trees (Flagstaff Urban/Wildland Interface)
- **Intermediate thinning—3/6** replacement trees (Flagstaff Urban/Wildland Interface)
- **Natural process restoration**, based on *Forest Forever!* (Southwest Forest Alliance, Kaibab and Gila National Forests)
- **Uneven-aged thinning** with unregulated old-growth (Edminster & Bailey, Flagstaff Urban/Wildland Interface)

This broad range of treatments incorporates a variety of perspectives on natural forest conditions and ways of restoring them—in our view, virtually any of these approaches is better than doing nothing. We've developed a brief historical perspective, below, of the development and modification of ponderosa pine ecological restoration in northern Arizona.

Interval Burning Experiments

As the problems associated with extended fire exclusion in southwestern ponderosa pine forests were first broadly recognized (Weaver 1951, Cooper 1960), initial research centered on simply re-introducing low-intensity fire. Now, over two decades of extensive local experimentation has shown that southwestern ponderosa pine forests do not regain natural forest structure from burning alone. Interval burning studies were initiated on the Fort Valley and Long Valley Experimental Forests in 1975 to test the ecological effects of re-introducing low-intensity fire at intervals ranging from 1 to 10 years (Harrington and Sackett 1990). Prescribed fires reduced accumulated fuel and mobilized forest floor nutrients (Covington and Sackett 1992) and moderately stimulated tree growth (Peterson et al. 1994), but thinned only a limited number of small trees. Even trees as small as 10 cm dbh were highly resistant to prescribed fire, so the study areas have retained thousands of trees/ha, well above presettlement reference levels even after 22 years of repeated burning. Techniques which increased fire intensity, such as ring firing, led to higher mortality of small trees but were difficult to apply due to the presence of continuous vertical fuels, the need for dry conditions, and the desire to protect old-growth trees from excessive scorch (Sackett 1980, Harrington and Sackett 1990). While the long-term interval burning studies remain in place, more comprehensive restoration experiments including structural restoration are the focus of current research (Sackett et al. 1996, Fiedler et al. 1996, Covington et al. 1997).

Key points:

- Fire alone is not effective in forest restoration.
- Fire re-introduction can kill old-growth trees, which have accumulated heavy duff fuels around the base.

Gus Pearson Natural Area

In developing thinning prescriptions to restore ponderosa forest structure, the four key concepts were (1) recreate presettlement tree density by conserving all living presettlement trees and replacing dead presettlement trees with live postsettlement trees; (2) restore the patchy presettlement

tree spatial pattern by retaining all living presettlement trees and locating replacement trees in the close proximity of dead presettlement trees; (3) maintain a wide range of age classes by retaining all living presettlement trees, thereby conserving genetic variability to the greatest extent possible; and (4) maximize the probability that replacement trees will survive to become old-growth trees by selecting healthy, vigorous replacement trees.

At the Gus Pearson Natural Area, extra replacement trees were retained in order to restore a different historic reference condition: the approximate diameter distribution at the time of initiation of long-term forest studies (1920). The residual tree density, 152 trees/ha, was substantially higher than the presettlement tree density, approximately 60 trees/ha. All trees over 16" were retained. Replacement trees were spatially grouped around dead presettlement tree remnants (snags, stumps, logs, stumpholes). In addition, small diameter trees were retained to approximate the inferred diameter distribution of a "reverse J" curve of an uneven-aged stand of trees (Edminster and Olson 1996). This diameter distribution appears consistent with the postsettlement (1920) stand structure, but not with presettlement structure (Covington et al. 1997). To avoid presettlement tree mortality due to fire girdling (Sackett et al. 1996), accumulated duff on the forest floor was removed manually before burning.

Key points:

- Structural restoration (tree thinning) plus fire is effective—tremendous response in herbaceous productivity and old-growth tree physiology and morphology (Feeney et al. 1998).
- Duff removal protects old-growth trees but is expensive.

Mt. Trumbull

Operations at the Mt. Trumbull experimental site have produced the greatest opportunities for learning and change. The adaptive management modifications applied at Mt. Trumbull are summarized in Table 1.

A formal marking guide was drawn up in 1995 at the inception of the Mt Trumbull restoration project. This guide listed the marking goals, described the age and external features of presettlement trees, and set a spatial search radius of 15 ft to constrain replacement trees close to presettlement remnants. These procedures were implemented in the 96-1 units, a total of 46 acres.

Concerns with the initial marking guide led to several changes. Principally, high-quality replacement trees were often lacking within the 15 ft search radius, while large healthy trees outside the search areas were removed. Sometimes no replacements at all could be found near one to many stumps. We examined whether the scientific basis might exist for larger search radius. Following the logic of presettlement regeneration patterns in the ash beds of consumed logs (White 1985), the search radius was extended to 30 ft and then to 60 ft, a distance still within the length of a large tree. Where replacements were entirely lacking, a system for mapping and replanting the site was devised. In practice, however, extending the search radius to 60 ft has nearly eliminated the problems of missing replacements as well as the cutting of the largest postsettlement trees, which could now be saved as replacements. These procedures were implemented at units 96-2 through 96-4.

Following the prescribed burning of unit 96-1 in October, 1996, other issues related to

marking were raised. The high mortality of Gambel oak led to a change in the oak treatment schedule. Rather than thinning oak together with pine, oaks are retained until after the burning, so that healthy, surviving trees can be selected as replacements. Presettlement oaks are still marked and protected (forest floor raking) prior to burning. Another concern was fire injury to replacement trees caused by burning of adjacent presettlement remnants such as stumps or snags. The 60 ft search radius and more attention to the hazard of proximity to rotten woody fuels are intended to minimize this type of injury in the future. Alternative fuel treatments are under study.

Table 1: Adaptive changes in restoration treatments over the last 5 years at the Mt. Trumbull restoration site.

Suggested Treatment Change	Source of recommendation	Action
Establish landscape-level control	NAU- Dr. Paul Beier	1996: Established approximately 500 ha as a control to be paired with 500 ha treated units.
Expand search radius	NAU-BLM	1996: Search radius expanded from 15ft. to 30 ft in 1996, and then to 60 ft. later in 1996
Adjust leave-tree ratio to account for stand biomass	Sierra Club, Center for Biological Diversity	1996: Leave-tree ratio changed from 1.5 trees left per remnant to 1.5 trees if leave trees > 16inches; 3 trees if leave trees < 16 inches.
Cooler burning prescription I	NAU, BLM	1996: Refined burning prescription resulting in cooler burns.
Re-seed with native plant mix	BLM	1997: Re-seeded the 13-acre part of 96-1 treatment unit with native seed. Monitored by NAU.
Retain all oak	BLM, NAU, Az G&F	1997: Retain all oak prior to burning, allow fire to thin
Adjust treatment plans to thin by allotments, so that cattle removal can utilize one swing (extra) allotment	NAU	Treatment plan altered to treat units in southern allotment 1997-1998, then northern allotment 199-2001.
Cooler burning prescription II	NAU, BLM, Az G&F	Treatments of under-burning prior to burning initiated 1998. Treatments of slash compaction initiated 1999.
Alternate slash treatment	NAU, BLM	1999: Slash compaction treatment initiated in Rye Flat unit.
Limit late spring burning to protect breeding wildlife habitat	NAU--Drs. Tom Sisk & Paul Beier	1999: Cut-off of April 15th initiated for all spring burns.

Excessive reduction of tree density and removal of large trees were central points in an appeal by the Sierra Club and Center for Biological Diversity of the BLM's environmental assessment for the treatment units subsequent to 96-1. Field trips and meetings among the environmental group

members, BLM staff, and NAU researchers led to broad agreements about restoration goals and procedures. However, to address the issue of reduced tree structural biomass (foliage, bark, etc.) in the post-restoration forest, biomass characteristics were compared. Using data from the demonstration plot in the 96-1 unit, the tree biomass in 1870 was compared with that of 1995 (pre-treatment) and 1996 (post-treatment). The effects of leave-tree diameter limits of 16", 20", and 22" were also compared. In the case of this particular plot, which had many large living presettlement trees, the 1996 mark was closest to the 1870 biomass. But where few or no living presettlement trees exist, or where replacements are very small, the post-treatment forest could have the same densities as the presettlement forests, but have less biomass. An alternative approach of leaving extra replacements was developed for the marking guide. The average size of replacement trees below 16" in units 96-2 and 3 was 12". The average size of residual trees over 16", including both replacements and presettlement trees, was 21". Assuming that the average size of larger postsettlement replacements is closer to 18", three 12" dbh trees can approximate the biomass of a 18" dbh tree. Therefore, where replacements are below 16" dbh, 3 such trees will be left for each presettlement remnant. Where replacements are larger, 1.5 trees will be left.

Key points:

- Various spatial patterns were tested to retain larger trees.
- More trees were retained if they were smaller (below 16" dbh), to more rapidly restore presettlement tree biomass levels. There are negative implications to leaving tree densities several times higher than those of the reference conditions, however: future tree girdling or removal may be necessary.
- Gambel oak thinning was deferred until burning to minimize fire injury in retained oak trees, a relatively fire-susceptible species.

Grand Canyon National Park

The preservation of natural ecosystem processes is at the heart of management policy for nature preserves such as National Parks. However, Grand Canyon National Park, which preserves the largest old-growth ponderosa pine forest in Arizona, is facing severe threats from high-intensity wildfire. Due to dense forests and high fuel loads, the park has had difficulty in re-introducing prescribed fire into the areas that need it most. Following a prescribed fire that exceeded prescription and had to be suppressed on the North Rim in 1993, an interagency review called for tree thinning prior to burning (Nichols et al. 1994). A proposal from NAU's Ecological Restoration Institute (Covington et al. 1997) for testing ecological restoration treatments on small plots in the park was approved following extensive review by Park Service and outside agency scientists and managers—the most thorough review of a research project in the history of the park. In addition to the restoration and control treatments, reviewers suggested two additional tests: a burn-only treatment, corresponding to current management policy, and a minimal thinning treatment, intended to encompass the least possible amount of thinning required for to protect old-growth.

The minimal thinning treatment will help conserve key ecosystem elements, such as old-growth trees, for some period of time into the future. Advantages to the minimal thinning approach include: (1) reduced short-term treatment impacts on soils, understory vegetation, wildlife habitat,

and esthetic values because of the reduced scale of thinning and wood removal operations; and (2) lower short-term costs, also due to the reduced scale of operations. Disadvantages to the minimal thinning approach include: (1) perpetuation of unnatural forest ecosystem structure, continuing the disproportionate dominance of trees relative to herbaceous plants and shrubs, implying that the normal ecological structures, functions, and habitats of the evolutionary environment will not be restored; and (2) maintaining an ecosystem which is still subject to catastrophic change, such as high-intensity wildfire, large-scale pathogenic outbreaks, or excessive mortality of old-growth trees, although certainly at a reduced level of risk compared to typical contemporary conditions. In sum, the minimal thinning treatment will substantially improve ecosystem health (see Kolb et al. 1994 for discussion of ecosystem health concepts). But wherever the management goal is to restore natural ecosystems, as is the case for many parks, wilderness areas, or natural areas, the minimal thinning treatment should be viewed as a stopgap measure to forestall the imminent loss of the slowest ecosystem variables such as old-growth trees and the soil erosion that follows high-intensity wildfire. The minimal thinning treatment can buy time, but in itself it is not a comprehensive ecological restoration treatment.

The **conceptual design** of the minimal thinning treatment is outlined next:

1. Thinning is targeted around individual presettlement trees—the "target" trees. Fuel structures need to be designed so that crownfire cannot cross to the target tree and the fire intensity of any wildfire at that tree is low enough to avoid mortality. Prescribed fire is an integral component of a minimal thinning treatment.
2. To prevent crownfire, timber fuel models (usually fuel model 9, other possibilities are 8 or even 10—see Anderson 1982) must be converted to grass-savanna fuel models (fuel model 2) in the vicinity of the tree. Fuel ladders and dense stands with interlocking canopies need to be thinned intensely around the target tree, then progressively less intensely moving away from the target tree.
3. To prevent excessive fire behavior (not crownfire) around the target tree, nearby trees and heavy ground fuels (woody and duff) must be cleared immediately around the tree.
4. To be consistent with general restoration goals, thinning should focus on the smallest and youngest trees. Presettlement trees will not be thinned. Wherever possible, the largest trees should be left, especially where such trees would have been selected as replacements for dead presettlement trees in a full restoration prescription. In no case should *more* trees be thinned under the minimal thinning prescription than would have been removed under a full restoration prescription.
5. The decision whether or not to remove any of the thinned material will be site-specific and related to the costs, complexity, and value of the thinned material. In many or most cases, a non-commercial approach to minimal thinning probably will make the most sense.
6. Future changes in the condition of the treated area need to be considered. Because most of the unthinned trees will be large enough to survive prescribed fires and many wildfires, their continued and accelerated growth in the thinned stand will tend to increase fire and competitive hazards for the target tree over time.

Key points:

- Agency-specific management concerns were incorporated into the experimental treatments (burn-only treatment, minimal thinning treatment).
- An initial restoration treatment aimed at reducing wildfire hazard and helping to protect

the old-growth trees, with minimal impacts and costs of thinning, was designed for the experiment.

- Landscape level studies of forest and fire regime changes complement the small experimental blocks.

Southwest Forest Alliance / Kaibab and Gila National Forests

The Southwest Forest Alliance (SWFA), a consortium of environmental activist groups concerned with southwestern forest ecosystems, prepared an ecological restoration guide called *Forests Forever!* (1996). In ponderosa pine forests, *Forests Forever!* called for retention of all old-growth trees, fuel treatments, thinning of trees below 16" dbh, especially those below 14" dbh, to a residual density of 50-250 trees/acre, occasionally fewer. The plan also called for maintaining contiguous forests and managing younger forests for the "natural variance of habitat conditions." In collaboration with the Gila and Kaibab National Forests, the SWFA tested thinning prescriptions based on *Forests Forever!* on small plots near Silver City, NM, and Williams, AZ. NAU's Ecological Restoration Institute established permanent plots on each study area to monitor the effects of the treatments.

The SWFA prepared Natural Processes Restoration Principles to guide restoration treatments. Although the retention of living old-growth trees is a central feature, the SWFA approach has not been directly to use presettlement forest evidence as a template for restoration. Instead, existing groups of large postsettlement trees are identified and conserved. The SWFA guide describes 4 stand types (large blackjacks [postsettlement trees, trees < 110-130 years old], small blackjacks, yellow pines [presettlement trees], and doghair thickets [dense postsettlement tree thickets]) and also has guidelines for "pre-commercial" trees and stands where commercial thinning or even-aged silvicultural practices had been previously applied. Approximately 20% of current forest conditions would receive no thinning treatment; untreated groups would be retained within visual range, a maximum of 200' apart.

Key points:

- The Southwest Forest Alliance developed a restoration thinning prescription and worked with the Forest Service and NAU to implement it.
- The SWFA treatments focus on modifying current forest conditions with less explicit concern for presettlement reference conditions.
- The treatment assumes that with minimal thinning natural processes can drive the forest to a desired condition

Flagstaff Urban/Wildland Interface

The Grand Canyon Forests Partnership is a collaborative group focusing on restoration of sustainable forest ecosystems and local economies in greater Grand Canyon ecosystems of the Colorado Plateau. Developing treatments to reduce crownfire hazard and restore forest health in the urban/wildland interface surrounding Flagstaff, AZ, has been the Partnership's first project. Working with the Coconino National Forest, the Partnership identified an initial treatment area in Fort Valley,

NW of Flagstaff, and selected a forest restoration approach proposed by NAU's Ecological Restoration Institute to reduction of crownfire hazard.

The initial phase of the Flagstaff urban/wildland interface (FUWI) project is a small-scale experiment to test different residual tree densities following restoration thinning. Three controlled experimental blocks were set up in and adjacent to the Fort Valley Experimental Forest to test three thinning prescriptions: full restoration thinning, leaving 1.5 replacements > 16" dbh or 3 replacements < 16" dbh per evidence of presettlement trees, and two levels of intermediate thinnings leaving more trees.

In some areas, tree densities higher than the reference condition may be desired for specific reasons, such as maintaining visual screening for homes or recreation sites. The **intermediate thinning** treatment is based on the same ecological considerations as the full restoration treatment, including retaining all living presettlement trees and using presettlement forest structure as a template. However, more replacement trees are retained on the site, with a greater excess of replacements, increasing the full restoration replacement density from 1.5 or 3 trees, to 2 or 4 trees, depending on replacement tree size. In the most dense option, replacement tree density is increased even further, to 3 or 6 trees. The intermediate thinning option does remove most crownfire potential, but the ecological cost of retaining extra trees is that understory productivity and diversity will not return to natural levels. Furthermore, the extra trees will continue to grow and eventually will contribute to re-closing of much of the canopy, reduction in resources available to understory plants, continued high competition affecting old-growth trees, and return of crown fuel continuity.

The Coconino National Forest prepared an environmental assessment of the first 10,000 acre FUWI treatment area, considering alternatives with various combinations of restoration treatments, as well as the no-action alternative. The primary thinning treatments were the intermediate restoration thinning (2-4) and minimal thinning. In response to concerns expressed by the SWFA, a 16" dbh cap was proposed for all thinning.

In the next phase of the FUWI project, several side-by-side demonstration areas, each approximately 100 acres in size, are being established to compare: (1) the SWFA thinning prescription; (2) the full restoration thinning prescription; (3) a "blend" of the SWFA thinning and full restoration treatments (still to be determined) and (4) an uneven-aged thinning prescription with an unregulated old-tree component. The uneven-aged (or "uneven-sized") prescription was developed by John Bailey of NAU and Carl Edminster of the Rocky Mountain Experiment Station following historic diameter distribution patterns measured in the early 20th century (see Edminster and Olsen 1996).

Key points:

- The Partnership project is a collaborative effort of many institutions seeking to reduce crownfire hazards and restore forest health in the Flagstaff area.
- In the pre-operational phase of the first treatment area, the Partnership is testing and comparing 6 different treatments (no-action, full restoration, modified restoration [2-4], modified restoration [3-6], uneven-aged thinning, SWFA natural processes restoration).
- All parties involved in forest restoration will continue to learn and adapt as projects move forward. We continue to seek to draw upon the best ideas from all approaches and learn from experimental tests.

PLANT COMMUNITY RESTORATION

Understory plant community restoration issues have been most pressing at Mt. Trumbull, in contrast to the relatively productive communities dominated by native plants at the other southwestern ponderosa pine sites. This section offers preliminary recommendations for understory plant restoration based on observations to date. The non-tree plant community (shrubs, grasses, sedges, and forbs) is a vital part of ponderosa pine ecosystems. Since the understory is strongly regulated by dominant overstory trees and by fire, the treatment activities associated with restoration have tended to focus directly on tree patterns and fire re-introduction. For restoration to be successful, however, the natural diversity and productivity of the understory plant community must be regained. Invasive and/or exotic understory species must be removed or maintained at tolerable levels.

The general definition of ecological restoration is the "**process of establishing to the extent possible the structure, function, and integrity of indigenous ecosystems.**" (Society for Ecological Restoration 1993). A detailed discussion of reference conditions is given in Moore et al. (1999). The basic point is that the concept of understory restoration is always viewed in the context of the natural ecological characteristics of the ecosystem. Reference conditions can be deduced from historical data, reconstructions of past conditions, or measured directly on undisrupted sites.

When is the understory community restored? Factors to be considered to determine if the ponderosa pine understory has been restored include:

- **Species richness and diversity** – the general goal is to re-gain the native species richness of the ecosystem. High species richness is has traditionally been viewed as desirable, except where species are exotics or ecologically undesirable in the ecosystem. The Simpson's diversity index (a weighted measure of richness and abundance) in the 13-acre seeded area of 96-1 was zero prior to treatment (no species fell on the transects) and 14.1 in the fall of 1999. Ninety-six species have been inventoried in the 13-acre area of the 96-1 unit and 94 species in the 33-acre area. However, diversity alone does not determine successful restoration. Compositional changes in the herbaceous community follow successional patterns, with annual forbs and disturbance-adapted perennials contributing much to the early diversity. These early-successional species are later replaced by the bunchgrass-forb community that may be more representative of the early herbaceous community.
- **Total plant cover** - cover should consist predominantly of native species. The total plant cover (based on plots inventoried by NAU) at Powell Plateau and Rainbow Plateau on the North Rim of the Grand Canyon were 35% and 37%, respectively. These Park sites can provide a point of reference because they are unlogged, ungrazed, and have supported 2-3 large spreading surface fires since 1879. At Mt. Trumbull, total cover in the 13-acre seeded unit was zero pre-treatment and 44% in 1999. Cover in the unseeded unit was 6% prior to treatment and averaged 25% in 1999. Using the Park sites as references, a target of around 1/3 cover (±33%) would appear to be adequate. This level has nearly been reached in the 96-1 units, 4 years after thinning and burning.
- **Ability to carry fire** at historic intervals is related to cover and biomass. A target was suggested by BLM staff of 500-1500 lbs/acre. However, this figure is highly dependent on the specific site conditions, especially soil type and soil moisture.
- **Life forms** - shrubs are currently at very low levels over most of northern Arizona's ponderosa pine forests. Historic levels are unknown.
- **Mycorrhizal assemblages** – critically important to plant establishment and maintenance, but relatively little is known about the mycorrhizal communities in ponderosa pine/ bunchgrass systems. Arbuscular mycorrhizae) increased in the first year following thinning at Fort

Valley near Flagstaff (J. Korb, unpublished data 2000).

Seeding issues:

Grasses

Because the soil seed bank at Mt. Trumbull is fairly depleted of native species of perennial grasses, these species should continue to be included in seed mixes. The only grass species that were captured by the transects in the unseeded area of 96-1 were blue grama, cheatgrass, squirreltail and muttongrass. Species captured by transects in the seeded area included Indian ricegrass, crested wheatgrass (non-native), western wheatgrass, blue grama, mountain brome, cheatgrass (non-native), squirreltail, junegrass, and slender wheatgrass. Several of these species were seeded. Although some of the seeded species were apparent in the surveys in 1998, there was a large increase in frequency of some of these species in 1999 (particularly the mountain brome and western wheatgrass). This increase was either due to delayed germination or spread of these species. Little bluestem was seeded and observed near the monitoring plot but was not captured by the transects so is most likely not germinating at a high rate. It appears that the perennial grass seeds require at least a period of 2-3 years (or a year of favorable moisture) to germinate. Squirreltail should be included in all seed mixes. It has a colonization strategy temporally similar to cheatgrass (Springer, personal observation) and may be able to out compete this species (Jones 1988).

Shrubs

Seeding shrubs in the 96-1 unit proved to be very effective, with the exception of Oregon-grape. Seeded species that successfully germinated were bitterbrush, skunkbush, snowberry, bluebunch elderberry and wax currant. All of these species were visible the year following seeding. Species which apparently sprouted after fire included silktassel, manzanita and buckbrush. Other species that naturally regenerated were serviceberry and sagebrush. With the exception of sagebrush, shrubs were not detected in the soil seed bank at Mt. Trumbull. However, some species apparently are still present in the form of underground rhizomes or buds and will regenerate following fire.

Forbs

Numerous species of early successional forbs are present as viable seeds in the soil seed bank. Forbs to include in seed mixes would be those that would colonize quickly in an effort to out compete undesirable non-native species or that would add nitrogen to the soil, namely members of the Asteraceae, Fabaceae and Scrophulariaceae families. The drawback is that new genetic material (subspecies and varieties) will be introduced into the area, even if these species are native to the Mt. Trumbull area. Palmer penstemon (*P. palmeri*) and scarlet beardtongue (*P. barbatus*) germinated well the first season following seeding. It is not known how successful the other forb species were following seeding.

Recommendations:

- Conduct seeding trials to determine length of time for native species to germinate when seeded.
- Conduct seeding trials to determine which species successfully germinate from seed mixtures.
- Continue literature review to determine germination requirements for native perennial grasses.
- Consider collections of seed from local seed sources, seed "garden".

Non-native species issues:

Arizona state-listed noxious weeds at Mt. Trumbull include cheatgrass, Scotch thistle, field bindweed, and common purslane. Russian thistle and horehound are also prolific in the 13-acre seeded portion of 96-1. Mullein and cheatgrass are the most common non-native species in the treated units. Experimental removal of mullein was tested, and the results are presented in section 4, **Vegetation Response to Restoration**..

WILDLIFE COMMUNITY RESPONSE

Wildlife studies have been a central feature of the Mt. Trumbull restoration project since its inception. NAU has sponsored several long-term large scale studies, complementing wildlife research done by partners: the Bureau of Land Management (research on forest bat communities) and the Arizona Game and Fish Department (research on deer, herpetofauna, turkey, bluebirds, and migratory birds). Information on partners' research status and results is available directly from them; this report summarizes NAU-sponsored research.

Effective experimental research on wildlife requires large-scale studies, due to the habitat size of mobile organisms, so wildlife research must be carefully planned. At Mt. Trumbull, studies have scaled from the forest stand to the landscape. Several of the stand-scale experimental sites completed initial restoration treatments in 1999-2000. Landscape scale experiments on herpetofauna (AGFD) and passerine birds (NAU) are in progress. Initial treatments are expected to be completed in 2001. Coordinating and accomplishing landscape-scale research are challenging, but this research will lead to an extensive body of knowledge of restoration effects on mobile species with wide application elsewhere in the Southwest.

Detailed summaries of the topics below can be found in section V., **Arthropod, Avian and Mammal Response**.

- The **butterfly** community response was monitored in the replicated experimental block design. Paired control and treatment units result in a powerful study design. Pre-treatment data and one year's post-treatment data have been collected. Initial data report increases in butterfly species richness and abundance in treated areas, most likely due to increased nectar resources.
- Community composition and abundance of **small mammals** were also examined utilizing the replicated experimental block design. Trapping efforts documented the small mammal community prior to treatment and following treatments. Species communities will then be analyzed for differences between treated and control units due to the treatment.
- Small mammals were tested for **hantavirus** (Sin Nombre virus), which is primarily carried in brush mice and encountered in smaller percentages in deer and pinyon mice. Researchers examined changes through time in hantavirus infection rates and any changes in carrying rates due to restoration treatments.
- Small mammals were trapped and radio-collared to examine habitat uses in restored and control units within one block. **Habitat use** assessments were established by following collared animals at night. Preliminary data show mice species differentiated between restored and control units.
- The **passerine bird** community response to restoration was initiated on a large scale, utilizing approximately 500 hectares of untreated land paired with 500 hectares of restored land. Pre-treatment data was collected 1997-1999. However, the treatment units will not be

completed until 2001, when post-treatment data collection will commence. Avian abundance, habitat selection and nesting success were examine.

- **Passerine birds** were studied for impacts due to the edges created by restoration treatments. As restoration treatments are implemented across the Mt. Trumbull landscape, edges are created that can negatively or positively affect the wildlife. This study examined the abundances of the bird community at edges and varying distances from edges, and their nesting success in restored and treated units.
- Habitat use by **tassel-eared squirrels** was extensively documented in the experimental blocks prior to treatment, recording the extent of clipped foliage, seed consumption, and nests. As thinning and burning treatments change the forest structure of the treatment sites, future monitoring will provide evidence of improvement or decline in squirrel habitat. By removing some young trees that were favored habitat, the strength of squirrel selectivity for specific trees can be estimated and management recommendations formulated.
- **Mule deer** winter populations and habitat use were measured on Kaibab Paiute tribal lands on the Arizona Strip in cooperation with Arizona Game and Fish Department (AGFD) research staff. Data on deer abundance and habitat are important to tribal resource managers and complement studies on traditional ecological knowledge as well as the AGFD deer study at Mt. Trumbull.
- Key **habitat characteristics** affecting invertebrate and bird communities have been measured at Mt. Trumbull. <u>Edges</u> between open, restored habitat and dense areas dominated by young trees are places of rapid change in microclimatic variables like sunlight and temperature. <u>Snags</u> are important habitat for many insect, bird, and mammal species. A complete census of the abundance, size, and habitat quality of all snags in the experimental blocks was carried out prior to thinning and burning treatments. Remeasurement of the permanently marked trees over time will enhance understanding of snag persistence, loss, and creation in the restored and control areas.

Continued monitoring over extended time periods—at least several decades—will be needed to determine the characteristics of wildlife responses to ecological restoration. Presently data is limited to pre-treatment or immediately post-treatment conditions, but animal communities will change together with the dynamics of plant community succession at Mt. Trumbull and other study sites. The data developed in these initial studies will be valuable for forest restoration planning throughout the Southwest.

LOOKING AHEAD

After five years, the **Restoration of Ecosystem Health** project has only begun to provide the long-term data ecological data that will prove invaluable for adaptive restoration and conservation of western ponderosa pine forests. This long-term project has been developed with permanent monitoring plots and designated control sites to provide continuing information on ecosystem responses. The early successional changes identified by researchers in this volume will be followed by maturation of the treated sites. Restoration ecology provides the "acid test" of ecological theory, showing the extent to which restoration treatments can influence ecological processes toward reinstatement of the sustainable, dynamic characteristics of the historic ecosystem. The Mt. Trumbull experimental site is the earliest large-scale, thoroughly-documented test site for southwestern ponderosa restoration.

To date, the project has successfully generated research on ponderosa pine ecosystem response to fire suppression and land degradation as well as the response of ecosystems to restoration

treatments. Collecting data from a range of ponderosa pine sites provides baseline knowledge of the range of variation specific to this ecosystem type. Measuring responses of ecosystem attributes to thinning and burning treatments allows specific hypotheses to be tested concerning restoration of sustainable ecosystems. This research is being used to assist land managers in ponderosa pine forest management. In addition to the management applications, this project is advancing ecological knowledge of plant succession, animal habitat preferences, and fragmentation effects on plant and animal populations. Researchers are currently taking advantage of treated and non-treated areas to examine responses of vegetation, birds, small mammals and butterflies. Ecological information contributes to the social and legislative debate surrounding restoration, especially in the case of designated Wilderness areas. Managers of wilderness areas around the nation will closely follow the results of this collaborative process.

Monitoring, adaptation, and interdisciplinary collaboration have been hallmarks of the experimental work at Mt. Trumbull. The project's progress reflects a mutual respect among the participants which constitutes an approach toward "restoring" partnerships between managers and scientists just as much as "restoration" of ecological conditions. The relationship has had deep benefits for all involved.

The value of information from the Mt. Trumbull experiment will only increase over time. Continued collaboration and enhanced resources for both field management and field science are essential to fully achieve the potential of this unique site. Even as restoration efforts are launched in other forests, the pioneering efforts at Mt. Trumbull must be pursued with continuing research so that the long-term trends and changes are fully understood.

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RESEARCH PROJECTS

I. MONITORING CHANGES IN SOUTHWESTERN FORESTS:

Dendroclimatic Reconstruction

Principal Investigator, Collaborators and Assistants: Joy Nystrom Mast

Main Funding Source: n/a

Summary:

Climate and disturbance history over the past several hundred years was recorded in the varying widths of tree rings. Climate has an important influence both on vegetation (species composition, establishment, growth, and mortality) and on the patterns of disturbances such as fire. Increment cores collected in 1996 from old ponderosa pine trees at Mt. Trumbull and Mt. Logan were crossdated and measured to develop a long tree-ring width chronology for the area. After maximizing the correlations between samples, two chronologies were developed. These chronology can be compared with tree age data and fire history results to search for past climate-plant-disturbance connections and to suggest potential future changes.

Management recommendations: Data collected to assist other researchers in analyses.

Keywords: tree ring, dendroecology, crossdating

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Fire ecology and forest structure in northern Mexico

Principal Investigator, Collaborators and Assistants: Pete Fulé, Wallace Covington, Abel García-Arévalo, Socorro González-Elizondo, Jorge Nocedal, José Medina-Flores, César Bonilla-Bravo, John Paul Roccaforte, Thomas Heinlein.

Main Funding Source: Restoration of Ecosystem Health, BLM-Department of Interior/ National Science Foundation/ USDA Forest Service, Pacific Northwest Research Station/ Instituto de Ecología, A.C.

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Ecological Reference Conditions in Forest Ecosystems Case Study: La Michilía Biosphere Reserve, Durango, Mexico. Presented at the Society for Ecological Restoration annual meeting, Austin, TX, September 30, 1998.

Fire regimes on an environmental gradient in a dry Sierra Madre forest. Presented to the annual meeting of the Southwestern Association of Biologists, Camp Tontozona, AZ, October 11, 1997.

Fire and Forests in Northern Mexico. School of Forestry seminar series, Flagstaff, AZ, September 24, 1997.

Changing Fire Regimes in Mexican Forests. Presented to the Ecosystem Management short course CEEM II, February 16, 1996, Flagstaff, AZ.

Summary:

Long-needled pine ecosystems in northern Mexico, closely related to the pine-oak forests of the Southwest, have been less severely impacted by fire exclusion than US ecosystems. Although rapid change is occurring in Mexican forests, a few unharvested areas with continuing frequent fire regimes remain. We are documenting natural ecosystem structures and fire disturbance regimes in northern Mexico to develop points of comparison with presettlement conditions in the Southwest. Such studies address questions that are difficult to answer because of ubiquitous fire exclusion in the US, such as the persistence of snags and downed biomass under frequent fire

regimes, the intensity and effects of 'low-intensity' fire in a frequently-burned ecosystem, and the universal character of forest changes following fire exclusion (increased tree density, increased fuels, etc.). In addition to directly supporting the southwestern ecological restoration research, these studies broaden our overall understanding of ecological structure and process, and will serve as a valuable resource for conservationists in Mexico. In 1996 we sampled pine-oak and mixed conifer forests over an elevational gradient at La Michilía Biosphere Reserve, in the Sierra Madre Occidental of Durango, Mexico. In 1997, we returned to Michilía to sample additional, including a high-elevation forest at the Reserve core which has not been subject to fire exclusion. This free burning forest, with structural and environmental characteristics similar to those of the southwestern US, will form an important resource for comparison to US ecosystems. We also remeasured permanent plots on a wildfire-control study which we initiated in 1996 following a high-intensity fire. Data from this site will be contrasted with the high-intensity fire studies in northern Arizona. Finally, we sampled our northernmost site to date in Mexico: a forest in southwestern Chihuahua. In 1999 we sampled landscape fuel components at La Michilía and visited potential field sites in Chihuahua to extend the Sierra Madre transect northward.

Summaries of project findings follow:

MESIC site: NW Durango, Mexico: Frequent, low-intensity fire is a key disturbance agent in the long-needled pine forests of western North America, but little is known about the fire ecology of the Mexican forests which have been least affected by fire exclusion. We compared fire disturbance history and forest structure at four unharvested or lightly-harvested study sites differing in recent fire history. Frequent, low-intensity fires, recurring between 4 to 5 years for all fires and 6 to 9 years for widespread fires, characterized all the sites until the initiation of fire exclusion in the mid-twentieth century at three of the four sites. Although most fires in the study area are ascribed to human ignitions, evidence of both lightning and human-caused burning was observed on the study sites. A possible connection between fire occurrence and climate was indicated by a correspondence between regional fire years and positive extremes of the Southern Oscillation index (SOI), which is associated with cold/dry weather conditions. Forest ecosystem structures differed in ways consistent with the thinning and fuel consuming effects of fire. Two sites with extended fire exclusion were characterized by relatively dense stands of smaller and younger trees, high dead woody biomass loading, and deeper forest floors. In contrast, a site which had burned following a 29-year fire exclusion period, and the final site where frequent fires had continued up to the present, were both relatively open forests dominated by larger trees. The recently burned sites had lower dead woody biomass loading, especially of rotten woody fuels, and more shallow duff layers. The high regeneration density but low overstory density at the recently burned sites is also consistent with the thinning effect of low-intensity fire. Long-term management and conservation strategies for these forests should recognize the historic role of fire disturbance as well as the potential for changes in fire intensity and ecological effects following extended fire exclusion.

Spatial patterns of forest structure: Patterns of spatial arrangement, tree density, and species composition were compared in three unharvested pine-oak forests under different recent fire regimes: (1) an uninterrupted frequent fire regime, (2) fire exclusion, and (3) fire exclusion followed by the return of fire. Regeneration was dense and highly aggregated at all sites but the frequent-fire overstory was random to uniform in spatial distribution and relatively open while the fire-excluded sites had clumped overstory trees with a high density of smaller trees. Dominance by sprouting species was greatest at the fire-excluded sites. Mortality was spatially aggregated at all sites, consistent both with thinning by fire and density-dependent mortality, but competitive self-thinning appeared insufficient to counteract the increased tree density without fire. The

return of fire after 29 years of exclusion reduced tree density but left overstory trees aggregated and led to vigorous oak and alder sprouting. Frequent fire disturbance is considered essential to maintain open pine forests; fire exclusion with or without subsequent fire appears to lead to denser forests dominated by smaller trees of sprouting species.

XERIC site: SE Durango/Zacatecas, Mexico: The ability of reserves to maintain natural ecosystem processes such as fire disturbance regimes is central to long-term conservation. Fire-scarred tree samples were used to reconstruct fire regimes at five study sites totaling approximately 230 ha in pine (*Pinus* spp.) and oak (*Quercus* spp.) forests of La Michilía Biosphere Reserve on the dry east slope of the Sierra Madre Occidental, Durango, Mexico. Study sites covered a 20-km environmental gradient of elevation, topography, and human land uses; plant communities ranged from oak-pine to mixed conifer forests. Fires were frequent at all sites prior to 1930, when large-scale grazing of domestic livestock was initiated. Widespread fires have been excluded from 4 out of the 5 sites since 1945, with an essentially uninterrupted frequent fire regime continuing only in the reserve core. Xeric sites had many, smaller fires, while mesic sites had fewer but larger fires. On a reserve-wide scale, a fire burned on at least one site nearly every year, usually in the dry spring/early summer season, but fire years were rarely synchronous among the sites. Fire occurrence was weakly related to the Southern Oscillation (SO) climate pattern; major reserve-wide fire years almost never coincided with wet SO extremes but only occasionally matched dry SO extremes. Maintenance of the long-term frequent fire regime in the reserve core is one indicator that the Biosphere Reserve model has been successful in conserving natural processes, but the protected area is small (7,000 ha). Because of the key role of frequent fire regimes in regulating ecosystem structure and function, restoration of the ecological role of fire disturbance is a desirable conservation strategy.

Effects of intense wildfire: An oak-pine forest burned by intense wildfire in April, 1996, and a companion unburned area were sampled 1 month and 1 year post-fire in La Michilía Biosphere Reserve, Durango, Mexico. Up to 90% of the trees were killed or top-killed in the burned area, but larger trees tended to survive so basal area was only reduced by 66%. Top-killing was relatively higher among fire-susceptible oaks and lower among fire-resistant pines. However, oaks were strong resprouters both in the canopy and at the base of top-killed trees. Damage codes based on crown scorch and bole char were highly accurate when predicting that a tree would die but substantially overestimated survivors. Most tree regeneration was top-killed in the fire but oak sprout density was 700% that of the unburned area by 1 year post-fire. Manzanita shrubs also resprouted vigorously. Herbaceous production and cover were lower after the first post-fire growing season in the burned area than the unburned area. Woody fuels and forest floor depth were also reduced. Although short-term fire effects indicate that the forest ecosystem has moved closer toward a savanna condition, remnant seed trees and sprouting trees are expected to maintain forest cover. Future herbaceous production is likely to increase in response to overstory mortality. Quantification of fire effects is helpful for supporting short-term management decisions since oak-pine forests cover millions of hectares in northern Mexico. As a long-term management strategy, however, we suggest that restoring the frequent, low-intensity fire regime may be desirable for ecological and economic reasons.

Management recommendations: (1) Forests in northern Mexico, closely related to southwestern ponderosa pine forests, contain rare examples of unharvested and frequently burned sites that serve as natural points of reference for degraded U.S. ecosystems. (2) Most Mexican forests have experienced extended fire exclusion, beginning in the 1930's to 1950's. Just like U.S. forests, all fire-excluded Mexican forests have undergone tree population irruptions and conversion to hazardous fire conditions.

Keywords: fire, long-needled pines, oak, madrone, alder, Mexico, Sierra Madre Occidental, spatial pattern, mixed conifer, Ponderosae, conservation, ecological restoration, juniper, madrone, mortality, herbaceous production, fuel

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Fire History

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Main Funding Source: Restoration of Ecosystem Health, BLM-Department of Interior.

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Summary:

Frequent, low-intensity fire regimes are characteristic of ponderosa pine throughout its range, but specific knowledge of the characteristics of presettlement fire patterns at Mt Trumbull is important to guide the re-introduction of fire and to permit future evaluation of the restored fire disturbance regime. Fire history reconstruction based on dendrochronological measurement of fire-scarred trees, stumps, and logs is being undertaken at Mt Trumbull to estimate the frequency and seasonality of presettlement fire as well as determining the date of fire exclusion and developing a record of any postsettlement fires. A key feature of the project is the landscape scale of sampling across the entire ponderosa pine forest, allowing us to explore questions of fire size, intensity, and variability within the ecosystem, issues which have exceeded the scope of many previous studies. Preliminary fire history results were presented in the 1996 annual report. The 1996 samples have been dated and a database has been prepared, but further analysis is needed with the complete data set to explore the landscape-scale fire regime. In 1997 the entire area proposed for treatment at Mt Trumbull, in addition to the wilderness areas and forested surrounding regions, was sampled. The sample set from the Mt. Logan wilderness was analyzed and reported to the BLM in May, 1998, and the Mt. Trumbull data were reported in November, 1999.

Detailed summaries from the Mt. Logan and Mt. Trumbull Wilderness areas follow:

Mt. Logan: See *Mt. Logan Wilderness Forest Structure.*

Mt. Trumbull: Ponderosa pine forests in the Mt. Trumbull Wilderness on the Arizona Strip have become dense with young trees and highly susceptible to catastrophic wildfire due to exclusion of the natural frequent-fire regime. As part of a broader regional ecological restoration study, the Mt. Trumbull Wilderness was sampled for fire scarred trees, vegetation, and fuels in

1997 and 1999. Reconstructed fire histories show that fires recurred about every 4.4 years prior to settlement, with larger fires burning every 9.5 years. Frequent fires ceased after 1863 in the Mt. Trumbull Wilderness, coincident with the time of Euro-American settlement around 1870, beginning a fire-free period that has lasted up to the present except for a few small fires and a larger 1989 wildfire. Current forests are dense, averaging approximately 1,200 trees/ha, and dominated by small trees. Throughout the wilderness, tree canopy cover averages over 65% and tree basal area is high, 35-36 m^2/ha. Understory plant cover is about 20% and understory species diversity averages 11.4 species/sample plot. Living and dead fuels, including plants, woody debris, and the forest floor, will easily support high-intensity wildfires. In contrast, the presettlement forest was relatively open, with tree density of approximately 62 trees/ha and basal area averaging 8.9 m^2/ha, dominated by large ponderosa pine trees. In ecological terms, prospects are good for restoring the Mt. Trumbull Wilderness to emulate the ecological structure and fire disturbance regime of the presettlement reference condition. The current forest condition is perhaps least affected by recent degradation of any site in the Uinkaret Mountains. However, ecological information is only one component contributing to the debate over appropriate management values and practices in wilderness areas on public lands.

Management recommendations: Frequent surface fires formed an important disturbance regime in Mt. Trumbull forests prior to the 1870 utilization of the area by Euro-American settlers. Presettlement fuel quantity and continuity supported frequent and widespread burning. Ignition sources were common and probably include human-caused as well as lightning fires. The general exclusion of fire for 130 or more years in the Mt. Trumbull area has led to hazardous conditions. Presettlement fire regime information serves as a point of reference for re-establishing surface fire regimes in these forests.

Keywords: Fire regime, dendrochronology, presettlement.

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High Intensity Fire Study

Principal Investigator, Collaborators and Assistants: Peter Fulé, John Paul Roccaforte, Amy Waltz, Judy Springer, Thomas Heinlein, W.Wallace Covington.

Main Funding Source: Restoration of Ecosystem Health, BLM-Department of Interior/ National Science Foundation/ USDA Forest Service, Rocky Mountain Research Station.

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Presentations/Proceedings:

Fulé, P.Z. Simposium Sobre Incendios Forestales. Presentation to the IV Congreso Mexicano Sobre Recursos Forestales, Durango, Mexico, November 26, 1999.

Fulé, P.Z. Ecología de Incendios en la Sierra Madre Occidental. Presentation to the Instituto de Ecología, SEMARNAP, CIDIIR-IPN, and UAJD, Durango, Mexico, July 6, 1999.

Summary:

Severe, stand-replacing fires are becoming increasingly common in ponderosa pine forests due to the high tree densities and heavy fuels accumulated over a century or more of fire exclusion. What kind of ecosystem structures and habitats appear following high-intensity fire?. Can these fires recreate conditions similar to presettlement forest patterns, or do different ecosystem structures emerge? To answer these questions, this study focuses on measuring ecosystem structure (trees, shrubs, grasses, forbs, dead biomass) in sites burned with high-intensity fire, reconstructing pre-burn conditions where possible, and comparing present and forecast conditions over the burned area. Two severe wildfires at Mt Trumbull were sampled in 1996, the Lava fire (approximately 20 acres) and the Logan fire (approximately 150 acres). A complementary study of a high-intensity 1996 wildfire at the Michilía study site in Durango, Mexico, was carried out. This study will follow permanent plots over several years in a forest which burned with high intensity following approximately 60 years of fire exclusion. Measurements were taken in 1996 (one month after the fire) and 1997 (one year after the fire). The Mexican results will be compared with the effects of high-intensity fire at Mt Trumbull and other southwestern sites.

Detailed summaries follow:

Intense fire: summarized in "Fire ecology and forest structure in northern Mexico" section.

Modeling changes in fire behavior: Potential fire behavior was compared under severe weather conditions in 12 ponderosa pine stands treated with alternative thinning prescriptions in the wildland/urban interface of Flagstaff, Arizona. Prior to thinning, stands averaged 474 trees/acre, 158 ft^2/acre basal area, crown bulk density 0.0045 lb/ft^3, and crown base height 19.2 ft. Three thinning treatments differing in residual tree density were applied to each of 3 stands (total of 9 treated, 3 control). Treatments were based on historic forest structure prior to Euro-American settlement and disruption of the frequent fire regime (*circa* 1876). Thinning reduced stand densities 77-88%, basal areas 35-66%, crown bulk densities 24-48%, and raised crown base height an average of 11 ft. Before thinning, simulated fire behavior under the 97^{th} percentile of June fire weather conditions was predicted to be intense but controllable (5.4 ft flame lengths). However, active or passive crownfires were simulated using crown base heights in the lowest quintile (20%) or winds gusting to 30 mph, representing the fuel ladders and wind gusts that are important for initiating crown burning. Under the identical conditions after thinning, all three treatments resisted crown burning. The degree of resistance was related to thinning intensity. It is crucial to remove thinning slash fuels through prescribed burning or other means. If not removed, slash fuels can cause crownfire behavior in the thinned stands under severe wildfire conditions. Finally, the crownfire resistance achieved through thinning will deteriorate over time unless maintenance burning and/or thinning is continued.

Management recommendations: Severe fires cause substantial negative impacts to forest ecosystems. Long-term effects include soil exposure to erosion, death of old trees, and establishment of exotic and early successional species. Modeling results indicate that treatments to reduce crown bulk density and raise crown base height will reduce forest vulnerability to

crownfire.

Keywords: Fire behavior, mortality, crownfire, slash.

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Modeling Forest Structural Change

Principal Investigator, Collaborators and Assistants: W.Wallace Covington, Peter Fulé, Stephen Hart, Robert Weaver.

Main Funding Source: Restoration of Ecosystem Health, BLM-Department of Interior/ National Science Foundation

Bibliography:

Covington, W.W., P.Z. Fulé, S.C. Hart, and R.P. Weaver. Accepted. Modeling ecological restoration effects on ponderosa pine forest structure. *Restoration Ecology*.

Summary:

FIRESUM, an ecological process model incorporating surface fire disturbance, was modified for use in southwestern ponderosa pine ecosystems. The model was used to determine changes in forest structure over time and then applied to simulate changes in aboveground biomass and nitrogen storage since exclusion of the natural frequent fire regime in an unharvested Arizona forest. Dendroecological reconstruction of forest structure in 1876, prior to Euro-American settlement, was used to initialize the model; projections were validated with forest measurements in 1992. Biomass allocations shifted from herbaceous plants to trees and nitrogen was increasingly retained in living and dead tree biomass over the 116-year period (1876-1992). Forest conditions in 1992 were substantially degraded compared to reference presettlement conditions: old-growth trees were dying at accelerated rates, herbaceous production was reduced nearly 90%, and the entire stand was highly susceptible to high-intensity wildfire. Following an experiment initiated in 1993 to test ecological restoration treatments, future changes were modeled for the next century. Future forest structure remained within the natural presettlement range of variability under the full restoration treatment, in which forest biomass structure was thinned to emulate presettlement conditions and repeated low-intensity fire was re-introduced. Simulation of the control treatment indicated continuation of exceptionally high tree density, probably culminating in stand-replacing ecosystem change through high-intensity wildfire or tree mortality from pathogens. Intermediate results were observed in the partial restoration treatment (tree thinning only); the open forest structure and high herbaceous productivity found immediately after treatment were gradually degraded as dense tree cover reestablished in the absence of fire. Modeling results support comprehensive restorative management as a long-term approach to conservation of key indigenous ecosystem characteristics.

Management recommendations: Long-term ecological process modeling indicates that restoration treatments of tree thinning and prescribed burning appear to sustain natural forest conditions.

Keywords: Presettlement, Arizona, Gus Pearson Natural Area, FIRESUM, process model, fire regime, biomass.

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Mt. Logan Wilderness Forest Structure

Principal Investigator, Collaborators and Assistants: Marcy DeMillion, Pete Fulé, Wallace Covington, Amy Waltz, ERI staff and students.

Main Funding Source: Restoration of Ecosystem Health, BLM-Department of Interior.

Bibliography:

DeMillion, M. 1999. Mt. Logan reference conditions and social preferences for ecological restoration. M.S. Thesis, Northern Arizona University.

Waltz, A.E.M., P.Z. Fulé, W.W. Covington. In prep. Changes in ponderosa pine forests of the Mt. Logan Wilderness. May 1998 report to BLM currently under revision for publication.

Summary:

Ponderosa pine forests in the Mt. Logan Wilderness on the Arizona Strip have become dense with young trees and highly susceptible to catastrophic wildfire due to exclusion of the natural frequent-fire regime and the effects of livestock grazing and logging associated with Euro-American land use practices. As part of a broader regional ecological restoration study, the Mt. Logan Wilderness was sampled for fire scarred trees, vegetation, and fuels between 1995 and 1997. Reconstructed fire histories show that fires recurred about every 5-6 years prior to settlement, with larger fires burning every 9-12 years. Frequent fires ceased after 1869-1879 in the Mt. Logan Wilderness, coincident with the time of Euro-American settlement, beginning a fire-free period that has lasted up to the present except for a few fires in the 1930's. Current forests were dense, ranging from approximately 700 to 3,000 trees/ha, and dominated by small trees. At both unthinned and thinned sites on basalt soils within the wilderness, tree canopy cover was over 50% and tree basal area was high, 39-40 m2/ha. Understory cover and species diversity were generally low, but slightly higher on cinder soils where shrubs have formed an important understory community and where tree density was somewhat reduced. Living and dead fuels, including plants, woody debris, and the forest floor , would easily support high-intensity wildfires. In contrast, the presettlement forest was relatively open, with tree densities ranging from approximately 80-100 trees/ha and basal areas ranging from 10-15 m2/ha, dominated by large ponderosa pine trees. In ecological terms, prospects are good for restoring the Mt. Logan Wilderness to emulate the ecological structure and fire disturbance regime of the presettlement reference condition. The current forest is similar to nearby ecosystems where thinning, burning, and fuel treatments are being implemented. However, ecological information is only one component contributing to the debate over appropriate management values and practices in wilderness areas on public lands.

Keywords: fire regime, forest fuels, forest soils, ponderosa pine, reference conditions, thinning

Management Recommendations: This study addresses the ecological changes to the forest structure on Mt. Logan since fire exclusion. Significant changes have occurred, altering the vegetative community structure and fire behavior. However, changes in management will have to incorporate appropriate wilderness guidelines within this designated wilderness area.

Phytolith Assemblages and Soil Characteristics from a Southwestern Ponderosa Pine/Bunchgrass Community

Principal Investigator, Collaborators and Assistants: Becky K. Kerns, Margaret M. Moore, Stephen Hart, Mike Timpson, Coconino National Forest, Lauren Labate, ERI students and staff.

Main Funding: NAU School of Forestry (McInntire-Stennis), NAU Graduate School, Restoration of Ecosystem Health in Southwest Forests, Department of Interior, BLM.

Bibliography:

Kerns, B. K. 1999. Phytolith assemblages and soil characteristics from a southwestern ponderosa pine forest. Ph.D. dissertation, Northern Arizona University, Flagstaff, AZ.

Kerns, B. K. In press. Diagnostics phytoliths for a ponderosa pine-bunchgrass community near Flagstaff, Arizona. The Southwestern Naturalist.

Kerns, B. K. 1999. Understory species composition corresponds to overstory canopy type in a ponderosa pine forest. Oral presentation and published abstract, 1999 Annual Meeting, Ecological Society of America, August 8, Spokane, WA.

Kerns, B. K. 1999. Soil phytolith assemblages and organic carbon isotopes from a southwestern ponderosa pine community. Oral presentation and published abstract, 1999 Meeting of the Society of American Archaeologists, March 26, Chicago, IL.

Kerns, B. K. and M. M. Moore. 1998. Reconstructing presettlement vegetation using soil phytolith assemblages from a southwestern ponderosa pine forest. Oral presentation and published abstract, 1998 Annual Meeting, Ecological Society of America, August 3, Baltimore, MD.

Kerns, B.K. 1998. Use of phytolith analysis in ecological research. School of Forestry Spring Seminar Series, Northern Arizona University, AZ, April 8. Invited technical session.

Kerns, B. K., and M. M. Moore. 1997. Use of soil characteristics and opal phytoliths to examine vegetation stability in a ponderosa pine/bunchgrass community. Poster presentation and published abstract, 1997 Annual Meeting, Ecological Society of America, August 5, Baltimore, MD.

Summary:

The goal of this research was to examine contemporary vegetation dynamics and use soil characteristics, phytolith analysis, and stable carbon isotopes to understand pre-Euro-American (presettlement) grass-tree vegetation dynamics and grass understory conditions. Study sites were located in northern Arizona, within the Fort Valley Experimental Forest, 15-km northwest of Flagstaff.

To assess changes in soil characteristics due to vegetation at the patch-scale and examine ecotone boundary stability, I examined soil profile morphology, pH, organic C, total N, C:N, lipids, and phytolith concentration from transects crossing ecotones between presettlement trees, postsettlement stands, and remnant grass patches. Presettlement plots had significantly lower A horizon pH and thicker O horizons compared to grass plots. Phytolith concentration was similar between plots, indicating grass cover was more spatially continuous in the past. We found few significant differences among plots for A and B horizon C, N, C:N and A horizon lipids and suggest the traditional forest-grassland soil paradigm might not apply in all forest-grassland

communities. Our results show C in the A horizon is correlated with O horizon accumulation (r^2=0.79). Because thick O horizon accumulation is probably a contemporary phenomenon linked to fire suppression, presettlement and postsettlement areas are most likely sequestering more C in the soil than in the past.

Using a phytolith classification system developed from local flora, I determined that modern soil phytolith assemblages reflected the overall species composition of the area, but local differences were detected, indicating that phytolith analysis is a promising tool for reconstructing vegetation patterns in this community. Contemporary grass species composition, subsurface soil phytolith, and soil organic carbon $\delta^{13}C$ data suggest that as overstory forest structure has changed over the past 120 years, grass production, and C_3 and C_4 species composition have become spatially segregated in distribution and that some species (specifically *Koeleria macrantha* and species in the genus *Bromus*) are being lost entirely from the community. $\delta^{13}C$ data suggests that C_4 grasses have increased relative to C_3 grasses on open canopy plots but have disappeared from forested areas; however, all soil phytolith assemblages were dominated by C_3 type grass phytoliths, indicating that the overall grass species composition was dominated by C_3 grasses in the past.

Management Recommendations: (Please note that these recommendations may not be applicable to the plant communities at Mt. Trumbull):

The overall goal of this research was to understand both presettlement and contemporary grass-tree vegetation dynamics and understory grass conditions. As part of these overall goals, development and evaluation of phytolith analysis as a historical reconstruction tool in southwestern ponderosa pine forests was also an important research objective. I suggest that phytolith analysis in ponderosa pine-bunchgrass communities has a promising future for understanding vegetation dynamics. Results indicated that the phytolith classification system and techniques used in this study appear to be quite efficient at predicting current extra-local species composition. Locally controlled differences in both grass vegetation and overstory structure were also detectable and the newly defined ponderosa pine spiny body type proved to be a sensitive indicator of overstory structure.

Fire exclusion, over grazing, logging, and climatic oscillations have created marked changes in southwestern ponderosa pine forests. Data from this study indicates that these changes have included: overall reductions in grass abundance, reductions in the relative abundance of certain understory grass species (*Koeleria macrantha* and *Bromus* sp.), spatial segregation of grass production to infrequent open areas, and the possible spatial segregation of C_3 and C_4 grass species. Moreover, both soil phytolith assemblage and stable carbon isotope data suggest that species composition was dominated by C_3 plant species in the past, and the present-day relative percentage of C_3 grasses to C_4 grasses might be a contemporary phenomenon. An increased proportion of C_4 grasses may be due to factors such as selection by grazers and/or increased temperature due to global warming.

Using the presettlement reference conditions determined in this study as a target for ecological restoration goals, I have the following recommendations for this plant community. These recommendations may not be applicable for all management objectives. Postsettlement tree density and fuels (O horizon) should be reduced using presettlement density levels as a target and open treeless areas should be established. In order to establish presettlement grass species composition, seeding with a mix that includes a higher proportion of native C_3 grasses (including *Koeleria macrantha* and native species in the genus *Bromus*) should be considered. Moreover, establishment of presettlement grass species composition for ecological restoration objectives

may not be possible without the removal or limitation of domestic grazers and also reductions in populations of native ungulate grazers. Reintroduction of frequent, low-intensity fire will be central to restoration as this is a keystone process for these ecosystems.

Although reference conditions can serve as a target for ecological restoration, establishment of presettlement structure should not be viewed or managed as a static, unchanging state. Rather the reintroduction of presettlement processes (such as fire and reductions in grazing, etc.) will allow the ecosystem to respond dynamically within its evolutionary context, or natural range of variability.

Keywords: C_3, C_4, fire suppression, forest-grassland dynamics, non-metric multidimensional scaling, ordination, opal, overstory-understory relationships

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II. CULTURAL CHANGES IN SOUTHWESTERN FORESTS AND SOCIAL IMPLICATIONS:

Indigenous Land Management Practices

Principal Investigators, Collaborators, and Assistants: Thomas Alcoze, Michael Stoddard, Matthew Hurteau, Brandon Oberhardt, and Charlie Commanda, Lisa Dunlop, Jerome Covington, Ecological Restoration Institute.

Funding: Restoration of Ecosystem Health in Southwest Forest, Department of Interior and Arizona Strip District BLM.

Bibliography:

Alcoze, Thomas, and Matthew Hurteau. In press. Implementing the archaeo-environmental reconstruction technique: rediscovering the historic groundlayer of three plant communities in the greater Grand Canyon region. In *The historical ecology handbook*, eds. Dave Egan and Evelyn Howell. Island Press Covelo, California.

Alcoze, Thomas, and Matthew Hurteau. 1999. Implementing the archaeo-environmental reconstruction technique: rediscovering the historic groundlayer of three plant communities in the greater Grand Canyon region. Society for Ecological Restoration Annual Meeting, September 23 – 25, 1999, San Francisco, CA.

Summary:

The Kaibab Restoration Project represents an important development in the field of Restoration Ecology. We are creating a model that applies the results and conclusions of ecological restoration research to contemporary ecological issues. Through our collective efforts as a crew and by the collaborative process exhibited in our actions and interactions with Tribal and community members we demonstrate and exemplify important factors essential for the implementation of ecological restoration on a landscape scale.

The purpose of the Kaibab Restoration Project is to apply research based knowledge about ecological restoration in the real-world, community context of the Kaibab Paiute Reservation at Pipe Springs, AZ.

Tribal Resolution: The Tribal Council of the Kaibab Band of Southern Paiutes issued a tribal resolution in 1998 that put into effect the partnership between the tribe and the Ecological Restoration Insatiate (then Program) at NAU. This partnership initiated the first ecological restoration field work on the Kaibab Paiute Reservation. The tribal resolution honors the governance of the Kaibab Paiute Tribe and formalizes the partnership in culturally sensitive ways. This resolution appropriately initiated the relationships we now have with leaders and elders in the Kaibab Paiute community.

Woodlands Inventory: A woodlands Inventory, funded through BIA, was successfully completed by ERI and Kaibab field crews, and supervisors from both the tribal and university communities.

Sagebrush/Antelope Bitter Brush Ecological Monitoring Plots: Members of the Paiute Tribal Council selected eight study areas in the summer of 1999, with the intention of increasing the amount of desirable winter forage for the resident deer population. An ecosystem-monitoring plot was designed to establish an inventory of the eight selected sagebrush/antelope bitterbrush communities. Measurements collected on the 66 plots within these sagebrush/antelope bitterbrush communities monitored:

-Herbaceous measurements: point-intercept, one meter quadrats which capture % cover and frequency of herbaceous species, and a 2X50 meter belt transect that a gave a more complete inventory of plant species present.

-Shrub measurements: a transect that captured % cover and heights and a 2X50 meter belt which captured frequency and life stages.

-Fuel measurements.

-Mammal transect using the occurrence of pellets and tracks to indicate the present of animal species.

Exotic Weed Monitoring Within a Recent Wildfire: Plots were established in August 2000 to monitor the spread of exotic plants, mainly cheat grass, with in the Moccasins Mountain Fire, which occurred in July 2000 and consumed more than 1500 acres. The purpose was to monitor the spread of cheat grass within the burn. Transects were established perpendicular to a road where the fire bordered existing cheat grass populations. A series of one meter quadrats were laid out both within the unburned area where cheat grass existed and within the burned area where all vegetation was consumed.

Seedbank and Mycorrhizae study: The goal of the seedbank study was to determine what plant species had a viable seed source in the seedbank. There are eight study areas located on Moccasin Mountain. We collected 528 total soil samples from the eight study areas. The

samples were then placed in the greenhouse to allow all viable seeds to germinate. We stirred the soil after identifying and removing each germinated specimen. Stirring the soil allowed the opportunity for any viable seed to germinate. The soil samples remained in the greenhouse for six months.

The goal of the mycorrhizae study was to determine the presence of endo and ecto-mycorrhizae. We collected ten soil samples from each study site and placed them in the greenhouse. We then germinated organic corn, a non-species specific host plant, in each sample. After six weeks of growth we collected the plants and prepared them for examination under the microscope. The microscope work will be completed by the end of November.

Purshia tridentata ***Mechanical Treatment:*** *Purshia tridentata* is a favored winter forage species for mule deer on Moccasin Mountain. The goal of the mechanical treatment was to test the effects of removing shrub competition from *Purshia tridentata* individuals. We installed two meter radius plots around 120 individuals to determine density and abundance of all species within the immediate area. We then applied two different mechanical treatments to 80 of the individuals using random selection. Forty of the individuals were left untreated as a control. We applied a thin only treatment to 40 of the individuals. This treatment involved cutting all shrubs inside the plot and placing the slash on the ground inside of the plot boundary. We applied a thin and scatter treatment to the other 40 individuals. This treatment involved cutting all shrubs inside the plot and placing the slash outside of the plot boundary.

Mule Deer Population Census: ERI field crew, faculty and staff participate in mule deer census for Kaibab Paiute Reservation. Initial study by Arizona Game and Fish of the Kaibab Plateau mule deer population was extended to include the east Zion herd which uses the Kaibab Reservation for winter range. A deer census was initiated with Danny Bulletts, Director of Wildlife, Parks and Recreation for the Kaibab Tribal Council.

Geographic Information Systems: Visits and collaboration plans with Dr. Joy Mast (NAU) and Dr. Earl Zimmerman, University of North Texas to incorporate GIS data for Kaibab Restoration Project research.

Habitat Mosaic Model for Range Restoration: This position paper presents a theoretical model for implementing ecological restoration in pinyon juniper grasslands. This integrated management strategy addresses the ecological issues of pinyon juniper expansion and sustainable economic development opportunities. This paper was presented as Society for Ecological restoration and will be published (see above bibliography).

Proposed Restoration Research: The Kaibab Restoration Project assisted the Kaibab Band of Paiute Indians with the development of a restoration management plan that was directed by the long-range environmental goals of the tribe. The plan resulted in a comprehensive social and economic development project that, when implemented will result in an integrated plan and start-up provisions to establish a demonstration site for the restoration and revegetation of pinyon/juniper grasslands ecosystems on the Kaibab Paiute Reservation. The project is based on the balanced initiatives of natural resource sustainability, economic stability, elementary through university education for Paiute and community youth and collaborative leadership to sustain a governance and social network for the continuation of this project.

Six strands comprise the framework for this integrated planning project: <u>Strand I</u>-Restoration applications to: 1) prevent the loss/waste of natural resources; 2) restore the land to support and sustain wildlife, culturally significant plant species, and animal species raised for economic gain; and 3) result in plant and wildlife ecosystems characterized by biodiversity; <u>Strand II</u>-Greenhouse for: 1) revegetation of restored landscapes and the propagation and marketing of native

grass seeds; 2) a demonstration training site for local youth; 3) strengthening and diversifying the local economy through a community led collaborative project; Strand III-Youth Camp to: 1) restore and revitalize traditional ecological land management knowledge; 2) equip young people to understand modern land management issues from a cultural and ecological perspective; and 3) support young people's development for education beyond high school; Strand IV-School District Partnership to incorporate the knowledge and skills of sustainable land management and traditional knowledge into school curricula; Strand V-Native American Interns Program to: 1) offer training in natural resources management and restoration skills and year-round employment on the reservation; 2) identify, train and support local youth to continue their education in natural resources careers in the Ecological Restoration Institute (ERI) at Northern Arizona University; Strand VI-Collaborative Leadership by the Kaibab Paiute Tribal council to coordinate and direct the agencies that will help accomplish the goals in each strand. For grant applications, see attached documents in appendix.

Proposed Carbon 13 Isotope extends our research on historic environmental conditions and resulted in the attached book chapter. This research study uses the analysis of carbon isotopes from soil samples to distinguish between soils laid down by woody versus herbaceous vegetation types. The results of this analysis can establish the historic distribution of these habitat types.

Proposed Pollinator Ecology and Restoration: Represents a collaborative research project with York University entomologist. This study explores the relationship between insect pollinators and burn size and distribution and is a factor in revegetation success.

Pilot Education Initiative: In the fall of 1999, faculty and students from the Center for Excellence in Education and the Kaibab restoration field crew, began a pilot study to bring restoration ecologists and teachers together to understand and communicate environmental concerns on the Arizona Strip. This pilot study resulted in a grant (EPA/KEEN) that extended community participation from two colleges at NAU to the Kaibab Paiute Tribe to the Fredonia/Moccasin School District (see grant document).

Proposed Kaibab Reservation Greenhouse: Greenhouse at Zion-ERI field crew and Jeff Bradybaugh, Director of Natural Resources at Zion, exchanged visits to study revegetation plans at Zion. The soil seed bank study, which requires greenhouse capabilities, received important information regarding greenhouse design and implementation. The revegetation and restoration concerns on the Kaibab Reservation were also examined.

Proposed Big Horn Sheep Reintroduction: This cooperative project is being investigated to determine the feasibility of reintroducing big horn sheep to the reservation. The ecological conditions required to sustain this culturally important animal are being examined.

Community-Based Achievements: The Kaibab Restoration Project is the beginning phase of a proposed long term, comprehensive, community-based, sustainable development initiative. It provides a model for distinct local/regional and cultural communities to understand the contributions and perspectives of other people attached to the land/resources of the region. The Kaibab Restoration Project also provides a model for ecologists, students and educators to examine global natural resources issues in a sociocultural context. The Kaibab Restoration Project will explore the feasibility of:

1) Coordinated natural resources education programs that: a) serve multiple representative populations in Arizona and Utah; and b) integrate scientific knowledge about ecological issues with social/cultural knowledge expressed and identified by regional communities;

2) Community-based natural resources action strategies for a region where three culturally

distinct communities are responsible for environmental education and ecosystem health of shared and adjacent land areas. All communities represented in the Kaibab Restoration Project's target populations share intense attachments to the land and resources of a) the Arizona Strip, b) the Greater Grand Canyon Region, c) northern Arizona and d) southern Utah. The sociocultural environmental issues of these important regional and national lands are embedded in the Kaibab Restoration Project.

A powerful example of the types of partnerships is evidenced by the following account. In the summer of 1999 the field crew was preparing to leave their camp site, having loaded the equipment and gear. We received a message. One of the Kaibab Paiute grandmothers needed to have some wood split. The entire crew welcomed this opportunity as a way for them to personally repay the Kaibab Paiute community for their generosity, cultural teachings and kind acceptance. Upon arrival at the home of this elder, we discovered that she could barely see and was unable to split the two cords of wood for her woodstove. For the next two hours, the crew split, hauled and stacked the wood. When this pleasant task was complete the crew loaded into the vehicles and returned to Flagstaff.

The following list of people and partnerships evidence the commitment of this project to its goal of ecological restoration in a real-world, community context and the types of community involvement that have been beneficial and energizing for the project.

Community Partnership Initiatives: The Kaibab Restoration Project's goal of incorporating restoration in a specific cultural context, resulted in various and complex partnerships. The specific communities are listed here and the accompanying documentation evidences the various ways the communities worked in partnerships.

Kaibab Paiute Tribe-Carmen Bradley, Tribal Chair, Danny Bullets, Director of Wildlife Parks and Recreation, Vivian Jake, Director of Environmental Program, Brenda Drye, Director of Cultural Resources, and Ben Pikyavik, Tribal Elder have generously provided their time, cultural knowledge and assistance to the field crew in each of the ERI research projects.

Zion National Park - Jeff Bradybaugh, Resource Management Chief, Art Latterall, Fire Officer provide continuing consultation on revegetation data collection and procedures, greenhouse technology and collaboration with Zion National Park site.

National Park Service –John Hiscock, Park Manager and Ben Pikyavik, Interpreter at Pipe Springs National Monument provide information specific to Pipe Springs/Kaibab Paiute reservation ecological and cultural history.

BIA – We have worked with the BIA to facilitate tribal environmental projects. BIA representatives include Lyman Clayton and Leon Ben, Jr., Phoenix Area Office Division of Forestry; Effie Begay, St. George Field Office.

BLM – We have worked with BLM personnel Roger Taylor, Dianna Hawks, Ken Moore, Brian MacPherson to explore options for the ecological restoration of pinyon juniper/sagebrush grasslands habitats.

Arizona Fish and Game – We have collaborated with representatives of the AZ Fish and Game Research Division, Supervisor for Research Ray Sweinsburg, to study mule deer population dynamics. The reintroduction of big horn sheep is also being examined with this agency.

Keywords: sagebrush/antelope bitter brush communities, deer population, ecosystem monitoring, exotic plants, cheat grass, ecosystem monitoring, *Purshia tridentata*, collaboration, community outreach, education.

Mt. Logan Wilderness Restoration Study: Social Implications

Principal Investigator, Collaborators and Assistants: Marcy Demillion, Martha Lee, Wallace Covington

Main Funding Source: Restoration of Ecosystem Health, BLM-Department of Interior.

Bibliography:

DeMillion, M. 1999. Mt. Logan reference conditions and social preferences for ecological restoration. M.S. Thesis, Northern Arizona University.

Summary:

A social survey was developed to gauge ecological wilderness restoration treatment preferences among "local" populations as defined by the Bureau of Land Management. Residents were asked about three ecological treatments, mechanical, non-mechanical, and prescribed fire, in designated wilderness. Residents were divided into positive, negative, or neutral responses to the above treatments, and compared.

The results from the social survey showed that 75% of the residents supported a mechanical treatment, 54% of the residents supported a non-mechanical treatment, and 55% of the residents supported a prescribed fire treatment. The most useful portion of my social research for managers was in the determination of underlying beliefs held toward each treatment method. For example, the belief that prescribed fire would burn out of control was held by all three groups (positive, negative, and neutral) and this outcome was bad. Underlying beliefs are important to consider because beliefs can be changed through the use of education. Through the use of both ecological and social research, wilderness restoration can be more successful by using socially acceptable treatment methods. The more the public is involved in choosing a restoration method, the more they will feel a sense of ownership of public lands.

Keywords: mechanical treatments, non-mechanical treatments, prescribed fire, thinning, social preferences

Management Recommendations: This study should be incorporated with the ecological study and a more intensive community involvement to determine wilderness restoration treatment alternatives.

III. LANDSCAPE LEVEL RESPONSE TO RESTORATION:

In fall of 1995, the Arizona Strip District of the Bureau of Land Management and Northern Arizona University's School of Forestry initiated a project to do adaptive restoration of southwestern ponderosa pine ecosystems to their natural conditions. This project is the largest ponderosa pine restoration project in the Southwest, and the first to incorporate operational treatments in a ponderosa pine restoration treatment.

Research has shown prior to Euro-American settlement, ponderosa pine forests of the southwest supported open ponderosa stands dominated by grasses, forbs and shrubs and frequented by low intensity fires every 2 - 7 years (Cooper 1960, Covington and Moore 1994). Land-use practices initiated by early Euro-American settlement contributed to the cessation of

fires, and the resulting dense "dog-hair" ponderosa stands common in the Southwest today. Dendroecological evidence at Mt. Trumbull points to similar changes since Euro-American settlement on the Arizona strip. The last widespread fire on Mt. Trumbull was in 1870, which corresponds to introductions of grazing by early settlers and initial logging.

A restoration guideline was implemented in 1995 that has been adapted since using adaptive management principles (see Table 1). The original restoration guideline called for thinning stands to density levels approximately those at pre-fire exclusion, or presettlement time. This was accomplished by retaining all living trees of presettlement origin (trees that were alive in 1870). In addition, for every presettlement remnant, i.e., snag, dead and down, cut stump, an additional 1.5 trees postsettlement trees were left as replacements. Originally, replacements were sought within a 15-foot radius from the presettlement remnant (i.e., stump). Records denote large, oak trees, randomly distributed among the forests. Today's oak clumps often represent younger ramets of these presettlement clones, even if all trees have germinated since fire exclusion. Therefore, we initially thinned all clumps to two or three oaks, to facilitate the growth of large oak. Adaptive changes have increased the replacement tree ration to 3 trees per presettlement remnant when the replacement trees were less than 16 inches diameter. We also increased the search radius for replacement trees from 15 ft to 60 ft, to maximize the quality of the leave trees. Finally, in response to oak mortality due to the initial burn, we've eliminated all pre-burn thinning of oak, and will assess oak densities again after the initial restoration treatment is completed.

Two levels of vegetation monitoring were incorporated to monitor these treatments: ecosystem monitoring on a large scale allows landscape-level baseline data for large-ranging population studies, while a smaller, replicated experimental block design provides replication for populations with smaller ranges. Both methods measure the same variables, the main differences are the scale (EM – large, EB – small), and the replications (EM – 1 site, EB – 5 blocks).

The following lists the basic methodology for the two sampling methods at Mt. Trumbull and the total number of sampling plots placed.

Ecosystem monitoring:

- Prior to treatment, 50m X 20m (0.1ha) monitoring plots were placed on a 300m grid covering approximately 1500 ha (3500 acres) across the landscape (Figure 1). A total of 269 plots were placed between 1995 and 1999, 151 will have a restoration treatment, and 64 will not be treated to serve as a control landscape, 34 are located within the Mt. Logan wilderness, and 20 are located within the Mt. Trumbull wilderness.
- Associated with the plot placement, fire scar sampling was conducted over the entire 1500 ha (3500 ac) site between 1995 and 1997.
- On each plot, current tree densities, tree age distributions, tree regeneration, herbaceous diversity and frequency, canopy cover, and fuel loadings were inventoried.
- Presettlement remnants were also inventoried on each plot to reconstruct the forest prior to Euro-American settlement.
- This data was used to determine plant and tree species compositions, age distributions, fuel loadings and presettlement reconstructions across the Mt. Trumbull landscape.
- As plots are treated, they are re- monitored, with repeated re-

monitoring on a schedule to be determined.

Experimental blocks:

- Across the Mt. Trumbull landscape, five experimental blocks were established ranging in size from 16 ha (40 ac) to 40 (100ac) ha across the landscape.
- Blocks were divided into 2 units, and each unit within a block was randomly assigned either control (no action) or restoration treatment.
- Forty 0.04 ha monitoring plots were placed in each block, 20 per treatment unit. On each plot, current tree densities, tree age distributions, tree regeneration, herbaceous diversity and frequency, canopy cover, and fuel loadings were inventoried.
- Restoration treatments on 4 of the 5 blocks were implemented in 1999, and post-treatment monitoring commenced summer 2000.

This section details the two scales of projects as described above, and other projects that have landscape-level implications.

Ecosystem Monitoring Project

Principal Investigator, Collaborators, Assistants: Wallace Covington, Pete Fulé, Margaret Moore, Amy Waltz, Tom Heinlein, Judy Springer, John Paul Roccaforte, ERI staff and students.

Main Funding Source: Restoration of Ecosystem Health in Southwest Forests, Arizona Strip District, BLM

Bibliography:

Roccaforte, John Paul, W. Wallace Covington, Margaret M. Moore, Hiram B. Smith, Amy E.M. Waltz, and Thomas A. Heinlein. Applied Restoration Research and Management in Southwestern Forest Ecosystems (poster). Society for Ecological Restoration International Conference. September 23 – 25, 1999. San Francisco, CA.

Waltz, Amy E.M., Peter Z. Fulé, W. Wallace Covington. Experimental restoration at the Mt. Trumbull Resource Conservation Area, Arizona (poster). Society for Ecological Restoration International Conference. September 23 – 25, 1999. San Francisco, CA.

Summary:

Long-term monitoring is essential to assess current conditions, reconstruct presettlement ecosystem structure, and evaluate the effects of restoration treatments. The standard ecosystem monitoring plot is 50 X 20 meters (0.1ha or 0.25 acre), designed with permanent markers to be a long-term monitoring unit. Rebar stakes and rock cairns mark the center origin and the four outer corners to ensure identical setup in subsequent surveys. The plot design is adapted from the Western Region Fire Monitoring protocol (National Park Service 1992), and measures various components of forest structure, including trees, shrubs, herbaceous plants, forest floor fuels, canopy closure, and photographic records. Further information is available in the 1996 Annual Report prepared by NAU.

Between 1995 and 1999, 269 plots were installed across the 1500 ha (3500 ac) landscape. Of those plots, 151 will have a restoration treatment, and 64 will not be treated to serve as a control landscape, 34 are located within the Mt. Logan wilderness, and 20 are located within the Mt. Trumbull wilderness. The current management plan for the wilderness areas includes prescribed burning as the only "active" management. Both wilderness areas have motorized vehicle restrictions. The control landscape was set up for studies incorporating animals with larger ranges. Both the passerine bird study (Paul Beier), the small herptile study (Arizona Game and Fish) and the edge effect study (James Battin) will incorporate the control plots into their study design. Currently, it does not serve as control for the ecosystem restoration as a whole and might be eligible for restoration treatments upon completion of the passerine bird study.

Areas of the Mt. Trumbull landscape currently being treated will be remeasured when treatment is complete. To date, a total of 16 plots, representing about 150 ha (350 ac) has been remeasured. This delay was primarily due to operational delays caused by appeals, lawsuits or lack of operators. With the addition of operators interested in the small woody material available at Mt. Trumbull growing, we are seeing an increase in the hectares treated per year. Over the next 2-3 years, all units containing the 151 treatment plots will be treated, and those plots remeasured. In addition to the initial post-treatment assessment, control and treatment plots will continue to be monitored on periodic increments over time, to compare the effects of restoration and a no action alternative on ecosystem structure and function over time.

Post-treatment analysis allows us to measure the response of ecosystem variables to restoration treatments. The results raise new questions, such as the success/cost of reseeding, the potential need for active exotic plant control, and what alternative fuel treatments are available to alter the response to the initial burn.

keywords: inventory, landscape-level scale, long-term monitoring, restoration treatments

Management Recommendations: The majority of this project is still in-progress, making it difficult to properly assess the restoration treatments and make recommendations. Researchers and land managers are constantly interacting to implement new thoughts and questions in the research plan.

Experimental Block Study

Principal Investigator, Collaborators, Assistants: Wallace Covington, Pete Fulé, Margaret Moore, Amy Waltz, Tom Heinlein, Judy Springer, John Paul Roccaforte, ERI staff and students.

Main Funding Source: Restoration of Ecosystem Health in Southwest Forests, Arizona Strip District, BLM

Bibliography:

Roccaforte, John Paul, W. Wallace Covington, Margaret M. Moore, Hiram B. Smith, Amy E.M. Waltz, and Thomas A. Heinlein. Applied Restoration Research and Management in Southwestern Forest Ecosystems (poster). Society for Ecological Restoration International Conference. September 23 – 25, 1999. San Francisco, CA.

Waltz, Amy E.M., Peter Z. Fulé, W. Wallace Covington. Experimental restoration at the Mt. Trumbull Resource Conservation Area, Arizona (poster). Society for Ecological Restoration International Conference. September 23 – 25, 1999. San Francisco, CA.

Summary:

Experimental blocks for controlled testing of the effects of ecosystem restoration manipulations are an important component of the landscape-scale sampling at Mt Trumbull. The experimental blocks were established at a series of five controlled study sites. Each **block** consists of a nominal 40-acre area divided into two similar **units**. Treatments—(1) ecosystem restoration and (2) control-- were randomly assigned to each unit.

The five blocks at Mt. Trumbull are large enough to allow for replicated measurements on plants, arthropods, and even small mammals. Many researchers have taken advantage of this design, and currently researchers are examining arthropod responses to restoration treatments, arthropod and bird responses to edges created by restoration treatments, small mammal population dynamics, small mammal habitat use, and hantavirus infection rates in small mammals.

All pre-treatment data, including vegetation, small mammal, soil seed bank, butterfly community and edge effect, were collected in 1998. Treatments were initiated in the winter of 1998/1999, with burning completed by spring 2000. Block 5 was dropped from the simultaneously treated design, due to operational difficulties. Block 5 will be treated and burned by 2001, and will still be used in the experimental design. However, the blocks treated in the same year represent true replication.

The treatments of these units are based on the 1998 marking guidelines, with 1.5 or 3 postsettlement trees left as replacements for presettlement remnants, depending on replacement tree size. To examine the effects of natural revegetation, no seeding will be done in these units. Pre-treatment herbaceous community analysis showed the five blocks vary considerable in their respective herbaceous communities. Other units on the landscape are re-seeded as treated, so the experimental block design will offer a contrast to these treatments, to better assess the advantages and disadvantages of seeding. This natural regeneration response to thinning and burning treatments will provide insight to other large-scale restoration treatments. The first post-treatment vegetation data were collected in summer 2000.

Keywords: randomized block design, ecological restoration, thinning, burning, seeding, experimental design

More Information: www.for.nau.edu/ecorest

A Potential Wilderness Treatment: Restoration Without Wood Removal

Principal Investigator, Collaborators and Assistants: Alan Kaufmann, Pete Fulé, Wallace Covington, ERI staff and students.

Main Funding Source: Restoration of Ecosystem Health, BLM-Department of Interior.

Bibliography: n/a

Summary:

This study was designed to test a treatment that would be suitable for application in areas where wood removal is not practical. Experimental treatment areas approximately 100m x 200m were designated along the peripheries of experimental blocks 2, 3, 4 and 5 (four treatment areas total). These areas were marked and cut in roughly the same fashion as the experimental blocks. To address higher tree densities, and corresponding higher fuel loads, in experimental blocks 4 and 5, more trees were left standing, and some trees were girdled instead of felled.

However, no wood was removed from the sites. Instead, the felled trees were lopped, bucked into 4-foot sections, and moved away from the retained trees as far was practical.

Due to operational difficulties, EB-5 was not treated by 2000, and effort was not concentrated there for post treatment measurements. Because the main difference between these treatments and the regular experimental block treatments was the additional fuel, we measured three additional fuel transects at each of the 12 plots within the Wilderness Treatment Demonstration Units (WTDU's), so that there are a total of four fuel transects for each plot.

Pre-treatment measurements were completed in 1999, experimental blocks 2, 3 and 4 were burned spring of 2000, and the WTDU's were remeasured summer of 2000. These units were paired with units treated with operational wood removal, more typical of larger study sites, and control sites. These data will be able to address differences in vegetation and fuel load response due to wood removal.

Keywords: wood removal, fuel treatments, fuel loading

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IV. VEGETATION RESPONSE TO RESTORATION:

Alternative Fuel Treatment Study

Principal Investigators, Collaborators and Assistants: Peter Gould, Jason Jerman, Pete Fulé, Daniel Murray, Matt Wencel and Shawn Knox.

Funding: Restoration of Ecosystem Health in Southwest Forests, Department of Interior and Arizona Strip District BLM.

Summary:

The Rye Flat unit of the fuel treatment study was measured in August of 1999. A small bulldozer was used to walk over the slash in the Rye Flat fuels treatment area. The bulldozer was successful in removing the majority of the vertical arrangement of the fuels. The bulldozer treatment was subsequently burned in January of 2000; the control for this portion of the study was burned in April. Although the bulldozer treatment has not been remeasured, it is apparent that the treatment was successful in greatly reducing fire behavior and crown scorching of both pre and post settlement trees. Natural herbaceous recovery of the site was observed in the spring of 2000, indicating that the dozer did not have a significant negative impact on the soils. Subsequent manual seeding has been successful as well.

The pre-thinning fuels treatment was measured and prepared in August and was burned in October of 1999. This treatment also appears to have been successful in reducing fuel loads but further evaluation of the treatment is required in order to determine its viability as a management tool.

There are plans for one more treatment that will explore small diameter pre-restoration thinning. It is expected that this treatment will be ready to be burned by the fall of 2001. Fuel accumulations in earlier restoration treatments at Mt. Trumbull caused unacceptable levels of crown scorch and tree mortality in some treatment areas. The three fuel treatments

mentioned in this summary are intended to explore options for reducing these levels of crown scorch and mortality.

An adjunct fuel treatment study was conducted to explore the use of jackpotting fuels around the bases of large post-settlement trees in an attempt to heat girdle them for wildlife habitat (snag) production. This treatment was burned in January and will be revisited in the spring of 2001.

Thus far, the bulldozer treatment appears to be the most likely option for managing fuel loading because of restoration. The initial response from Greg Taylor, Arizona Strip BLM, appears to be very favorable and this treatment is likely to be utilized on a larger scale in 2000.

Keywords: fire behavior, fuel accumulation, fuel reduction, thinning, tree mortality.

*Effect of Thinning and Sprouting on Gambel Oak (*Quercus gambelii*)*

Principal Investigator, Collaborators and Assistants: Jeanmarie Onkonburi, Wally Covington, Peter Fulé, Amy Waltz, Chris Baker, Jay Benallie, Codey Carter, Peter Gould, Dean Keltner, Judy Springer, ERI staff and students.

Funding: Northern Arizona University, School of Forestry, Restoration of Ecosystem Health in Southwest Forests, Department of Interior, BLM.

Bibliography:

Onkonburi, J. 1999. Growth response of Gambel oak to thinning and burning: implications for ecological restoration. Ph.D. Dissertation. Northern Arizona University.

Summary:

The purpose of this research is to examine the potential for restoration of large Gambel oak (*Quercus gambelii*) trees in northern Arizona, specifically by discovering ways in which the growth rate of existing old-growth Gambel oak trees can be increased, and the growth rate of replacement large-sized oak can be enhanced. This study uses retrospective ecosystem analysis techniques to determine the effect of thinning and prescribed burning on Gambel oak. Results indicate that pine thinning produces the greatest increase in Gambel oak growth, oak thinning tends to increase the growth of the remaining oak trees, and prescribed burning produces variable impacts on Gambel oak growth rate. The magnitude of the increase due to pine thinning ranged from 1.4cm to 5.7cm in diameter growth per tree over a 25-year period. Over a 15-year period, oak thinning may increase the diameter of residual Gambel oak trees and additional 0.2cm in diameter, although further research is indicated in this case. Prescribed burning produced a range of growth responses in Gambel oak trees that ranged from an increase of 3.2cm to a decline of 0.7cm in diameter over a 10 year period. These growth changes are in addition to the 0.15cm annual diameter growth that would be predicted for a 25cm dbh Gambel oak tree growing in Arizona. Recommendations are made for the use of thinning and burning in future adaptive management experiments focused on Gambel oak restoration, as well as for comprehensive ecosystem restoration and management.

Keywords: overstory competition, growth release

Management Recommendations: please see accompanying dissertation.

Inventory and Assessment of the Mt. Trumbull Snag Resource

Principal Investigator, Collaborators and Assistants: Justin Waskiewicz, Pete Fulé, Carol Chambers, Wallace Covington.

Funding: Restoration of Ecosystem Health, BLM-Department of Interior

Bibliography:

Waskiewicz, Justin. 2000. Inventory and assessment of the Mt. Trumbull snag resource. Senior Thesis, Ecological Restoration Institute, May 9, 2000.

Summary:

Standing dead trees, or "snags" are an important component of forest ecosystems. Ecological restoration projects in the ponderosa pine aim to re-establish historic forest structure through thinning and understory burning. Such treatments are very likely to have and impact on the snag resource of a forest by 1) removing existing snags, either through cutting or prescribed fire, 2) creating new snags and 3) by retarding the decay of others.

Snags were inventoried on all five experimental blocks. The majority of snags across the sites were oak snags, although this was variable between sites. Bird foraging and excavation was much higher in pine snags than in oak snags, probably due to snag size. Pine snags averaged 46.7cm, while oak snags averaged 14.2cm dbh. Death date patterns were examined from trees that still had sapwood. High peaks of tree death seem to follow severe drought years. This data were also used to examine the effectiveness of existing snag classification codes, which appeared inconsistent, making large jumps or even reverse trend as classification number increases. The inconsistencies were more apparent in pine than in oak. Data were also collected on ant infestation, which were found more often in large pine snags.

This study was done prior to any treatment in the experimental blocks. As such, it serves as a baseline dataset for future studies of effects of restoration treatments on snags.

Keywords: prescribed fire, ants, birds, foraging, snag cavity, diameter distribution, decay classes, decomposition classes

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*Mullein (***Verbascum thapsus***) Removal Treatment*

Principal Investigator, Collaborators and Assistants: Walker Chancellor, David Huffman, Judy Springer, Pete Fulé, Wallace Covington, Amy Waltz, ERI staff and students.

Main Funding Source: Restoration of Ecosystem Health, BLM-Department of Interior.

Bibliography:

Chancellor, W. and J.D. Springer. Can wooly mullein (*Verbascum thapsus*) be controlled? Steps Toward Stewardship: Ponderosa pine ecosystems restoration and conservation conference. April 25-27, 2000, Flagstaff, AZ.

Summary: By causing forest floor disturbance, ecological restoration treatments that include tree thinning and prescribed fire can result in conditions favorable for the establishment weedy plant species such as wooly mullein (*Verbascum thapsus*). Weedy exotic plants often have the potential to inhibit the establishment of native understory species. Wooly mullein is an introduced Eurasian biennial that produces approximately 180,000, long-lived seeds during the second year of its life cycle (Gross and Werner 1978). The seeds germinate over a wide range of environmental conditions and require only moisture and exposure to light (Gardner 1921).

This study was conducted in the Mt. Trumbull Resource Conservation Area and was designed to test the efficacy of various methods for controlling populations of wooly mullein within a 13 ha forest unit that had been thinned in 1996 according to ecological restoration guidelines. Six mullein control treatments were applied in 1999 to 24 (four replicates each), 5 x 5 m plots. Treatments were: 1) removing entire mullein plants by hand-pulling, 2) using trimming shears to cut mullein at the basal rosette, 3) spot spraying each mullein plant using RD2 (herbicide often used for weed reduction), 4) broadcast spraying entire 5 x 5 meter plots with RD2, 5) removing the seed heads of mullein plants after bolting, and 6) control (i.e., no treatment). Each treatment was replicated in four plots. Pretreatment data collected included total stem count of live and dead mullein within interior 2 x 2 m subplots and current phenophase of each living mullein plant. In August 1999, the plots were remeasured. Total number of mullein plants was counted and plants were classified as seedling, rosettes, in flower, bolting, declining, healthy, or dead.

One-way analysis of variance (ANOVA) was used to test for main effects ($p \leq 0.10$) of treatments on numbers of mullein plants in different life stages (e.g. seedlings, adults) and conditions (e.g., live, dead). When main effects were found, Bonferonni's post-hoc test was used to examine pairwise differences in treatment group means. Similar analyses were performed to test for treatment effects on mullein population changes, comparing pre- and post-treatment data.

At pre-treatment, no differences existed in population characteristics between plots (Table 1). Mean number of mullein plants across all plots was 72.8.

Table 1. Mean number and range of plot values for seedlings, live plants, and total plants for all plots chosen for treatment.

Life Stage	Mean	Range
Seedlings	61	0-550
Live Plants	48.2	3-165
Total Plants	109.2	3-583

Mullein control treatments did not significantly affect the mean number of seedlings, adults, rosettes, bolting, healthy, or dead plants (post-treatment data) due to high variability among plots. However, hand-pulling treatments reduced the mean number of adult plants by 74 percent. Also, more declining plants were found in herbicide treated plots than in plots with other treatments. Spot spray, total spray, and hand-pulling treatments significantly reduced the number of flowering plants in plots (Table 2). Less than 4% of plants in herbicide sprayed plots flowered and less than 2 percent flowered in hand-pulling plots.

Table 2. Post-treatment means for flowering mullein plants across all treatments.

Treatment	*Mean*
Spot Spray	1.0 b
Total Spray	.75 b
Seed Clip	32.75 a
Control	27.25 a
Basal Cut	24.5 a
Hand-Pulling	2.0 b

Treatments that reduce the number of flowering plants have potential to control mullein populations over time by slowly depleting the number of seeds in the soil seed bank. To use this approach, successive treatments are therefore necessary. Hand-pulling may be a viable alternative to herbicide treatments in certain situations.

Literature Cited

Gardner, W. A. 1921. Effect of light on the germination of light-sensitive seeds. *Botanical Gazette*, **71**, 249-288.

Gross, K. L. & Werner, P. A. 1978. The biology of Canadian weeds. *Canadian Journal of Plant Science*, **58**, 401-413.

Management Recommendations: Future studies should incorporate natural successive properties of mullein. Please see attached report for recommendations based on these experiments.

The Soil Seed Bank: Implications for Ecological Restoration

Principal Investigator, Collaborators and Assistants: Judy Springer, Margaret Moore, ERI staff and students.

Main Funding Source: Restoration of Ecosystem Health, BLM-Department of Interior.

Bibliography:

Springer, J.D. and M. M. Moore. 1999. Relationship of soil seed bank to aboveground vegetation in an area undergoing ecological restoration. Poster presented at the Ecological Society of America National Conference, August 8-12, 1999, Spokane, WA.

Springer, J.D. and M.M. Moore. 1997. Soil seed bank in southwestern ponderosa pine: Implications for large-scale ecological restoration. Poster presented at the Society for Ecological Restoration International Conference, November 12-15, 1997, Fort Lauderdale, FL.

Springer, J.D. 1999. Soil seed bank in southwestern ponderosa pine: implications for ecological restoration. M.S. Thesis. Northern Arizona University.

Summary:

The objectives of my study were to: 1) obtain a baseline estimate of the plant species in the soil seed bank in a southwestern ponderosa pine forest prior to ecological restoration treatments (such as tree thinning and prescribed burning); 2) determine the relationship between soil seed bank species and the aboveground vegetation; and 3) determine species composition and seed density in the forest floor organic matter (O horizon) versus mineral soil.

Results from the baseline study indicate that overstory canopy type has a significant influence on the species in the soil seed bank. In general, annual and biennial species are found in greater numbers in the soil seed bank than perennials. From a total of 38 species, the most common species in the soil seed bank were *Verbascum thapsus, Leonurus cardiaca,* and *Conyza canadensis.* Six species were non-native and few perennial grasses emerged in seed emergence trials.

In an area undergoing ecological restoration, 14 species emerged in seed emergence trials from seed bank samples collected after overstory trees were thinned and prior to prescribed burning, with an estimated seed density of 3,152 seeds/m^2. The most common species were *Collinsia parviflora* and *Verbascum thapsus*, which accounted for 45% and 30% of the germinants, respectively.

Fifteen species were observed in the aboveground vegetation at this same site after thinning. Of these, *Collinsia parviflora* was the most common species. Although *Verbascum thapsus* accounted for 30% of the viable seeds in the seed bank, it accounted for only 3% of the plants in the aboveground vegetation. There were approximately 101 plants/m^2 in the thinned area, but only 0.4 plants/m^2 in the nearby unthinned control. There was a significant correlation between aboveground vegetation and the seed bank in the thinned area, but not in the control.

There was a significantly larger number of seeds in mineral soil than in the O horizon. However, a significantly greater number of non-native species occupied the O horizon versus the mineral soil. There was a significantly greater number of viable seeds at the 0-5 cm depth compared to the 5-10 cm depth (including both organic matter and mineral soil).

Keywords: seeding trials, soil seed bank, revegetation, native seed, ecological restoration, ponderosa pine, seed bank

Management Recommendations: Because perennial grasses are not well represented in the seed bank at Mt. Trumbull, it may be necessary to seed native grass species to meet particular management goals and to achieve target restoration goals.

Conduct baseline inventories of the soil seed bank prior to initiating thinning and burning to determine species that will emerge following ecological restoration treatments. These studies can also be used to determine if additional seeding of native species or control of non-native species may be necessary to restore diversity and structure to areas undergoing ecological restoration.

Future research needs include examining the role of fire after thinning on the soil seed bank, competition between the seedlings emerging from the soil seed bank and those in seeding mixtures (as well as interspecific competition in the soil seed bank), the distribution of seeds with depth in areas which have not been thinned, and further refinement of a regression equation to predict aboveground vegetation from the soil seed bank.

More Information: www.for.nau.edu/ecorest , Judith.Springer@nau.edu

Seeding vs. Natural Regeneration

Principal Investigator, Collaborators and Assistants: Judy Springer, Margaret Moore, Amy Waltz, Pete Fule, Wallace Covington, ERI staff and students.

Springer, J.D., A.E.M. Waltz, P.Z. Fule, M.M. Moore and W.W. Covington. 2000. Seeding versus natural regeneration: a comparison of vegetation change three years post-treatment. Steps Toward Stewardship: Ponderosa pine ecosystems restoration and conservation conference. April 25-27, 2000, Flagstaff, AZ.

Summary:

The decision whether to seed with native species following restoration treatments should be based on existing vegetation, species present in or absent from the soil seed bank, past management history, microclimate conditions and soils. We installed three permanent monitoring plots in two areas (total 18.6 ha) at Mt. Trumbull, Arizona. Trees were thinned and the sites burned in 1996 and 1997. A five ha area was seeded with native shrub, grass and forb species; the remaining 13.6 ha were unseeded. Pre-treatment species richness ranged from 0-5 species per plot. Thirteen graminoid and 8 shrub species occurred in the seeded area, while the unseeded area contained 4 graminoid and 4 shrub species. The greatest increase in species richness in both seeded and unseeded plots occurred approximately 1.8 years post-treatment. Perennial native species dominated plant cover by 2.8 years, although annual native forbs dominate the soil seed bank. Perennial grasses are nearly absent from the seed bank. The seeded area had the highest diversity, but it also had twice as many non-native species (14 vs. 7 in the unseeded plots). By August 1999, maximum species richness reached 51 species on the seeded plot. Of these species, 80% were native. Although seeding increases diversity, it may also have the long-term tradeoff of introducing new genotypes and species, both native and non-native.

Keywords: Revegetation, seeding, ecological restoration, ponderosa pine, native species, natural regeneration.

Management Recommendations: Further effort should be made to collect seeds in areas undergoing restoration to maintain the genetic material adapted to that area. Seeding trials should be conducted to determine length of time from seeding to germination and to determine seeds that will germinate in areas undergoing restoration.

V. ARTHROPOD, AVIAN AND MAMMAL RESPONSE:

Bird Abundance and Diversity prior to Restoration Treatments for Old-Growth Ponderosa Pine

Principal Investigator, Collaborators, Assistants: Paul Beier, Tammi Lesh, Holly Petrillo, Justin Waskiewicz,

Main Funding Sources: Arizona Game and Fish Heritage Grant, DOI grant to WW Covington, and Restoration of Ecosystem Health in Southwest Forests, BLM.

Bibliography: The data collected on this project formed a substantial portion of:

Lesh, T. D. 1999. Habitat selection by breeding passerine birds in pine-oak forests of northern Arizona. MS Thesis, NAU School of Forestry.

Lesh, T. D. 1999. Selection of foraging habitat by passerine birds in pine-oak forests. Oral presentation at Arizona-New Mexico meetings of The Wildlife Society, February 1999.

Lesh, T.D., P. Beier, and S. S. Rosenstock. in prep. Selection of foraging habitat by passerine birds in pine-oak forests. anticipated submission in November 2000.

Summary:

Our objectives were to observe avian responses to the restoration treatments by collecting data on passerine birds both before and after treatment in two 400-ha Areas (Treatment Area and Control Area). Dependent variables are bird diversity, bird abundance, reproductive success, selection of nest sites, and selection of foraging sites. Significant bird responses will be detected by a significant interaction between Area (Treatment, Control) and time (Before Treatment, After Treatment, with 2-3 years of data for each time period). The use of these several related dependent variables will allow us not only to observe gross changes in populations (e.g., more western bluebirds and fewer western tanagers after treatment) but also to make inferences about the mechanisms underlying these changes (by interpreting these changes in light of shifts in selection of foraging habitat, selection of nest sites, and reproductive success of these species) and to evaluate the significance of the changes (by considering both abundance and reproductive success).

Due to delays in the treatment schedules, we have collected only pre-treatment data (for 3 years, 1996 through 1998). We felt it would be a waste of resources to collect additional years of pre-treatment data, and we are eager to collect post treatment data as soon as possible.

Methods

We indexed presence and abundance of passerine birds by 8-minute point counts on circular fixed-radius plots (Ralph et al. 1993), tallying all birds heard or seen within 75-m of the point. We established 46 census plots on the Control Area and 48 plots in the Treatment Area, with 3 counts per station in each of the 3 years.

We monitored reproduction for a suite of 8 focal species that would be expected to respond to the treatments. To do so, we established six Nest Search Grids (3 on the Control Area and 3 on the Treatment Area, 36-ha each). We monitored each nest every 2-7 days until the nest failed or until the young birds apparently left the nest.

To quantify assess habitats selected for nesting and foraging, we measured vegetation characteristics on 287 plots centered on bird nests, 319 plots centered on bird foraging locations,

and 175 plots at pseudo-random locations available to birds (grid points). We studied nest site selection for 8 focal species (Table 1) and foraging habitat selection for 7 focal species (Table 2). We also studied nest site selection at a finer scale, namely the nest tree, comparing nest trees to trees available in different species, size classes, and tree class (snag versus live).

Results

The most abundant species across the 2 years were white-breasted nuthatch, Grace's warbler, mountain chickadee, pygmy nuthatch, western tanager, yellow-rumped warbler, solitary vireo, spotted towhee, western bluebird, Steller jay, dark-eyed junco, and gray flycatcher. Brown-headed cowbirds were extremely rare before treatment. These nest parasites may increase in the more open post-treatment landscape, especially if grazing animals maintain a low stubble height.

The Control and Treatment Areas did not differ in average species richness (8.4 species per point on the Control Area, 8.5 on Treatment Area) or average abundance (10.6 and 10.5, respectively). However, the species composition did differ slightly, with 9 species more abundant on the Control Area (none of which was a focal species for reproduction or habitat selection, and only 1 species –yellow-rumped warbler – was among the 12 most abundant) and 6 species (including no focal species, and none of the 12 most abundant) were significantly more abundant on the Treatment Area. These relatively slight baseline differences should not cause any problems in making inferences when post-treatment data become available.

A power analysis of pre-treatment data indicates that we need 30 successful nests to detect a shift of 30% at an alpha of 0.10, and 39 nests at an alpha of 0.05. Thus our sampling effort (Table 1) will be able to detect biologically significant changes in nest success for 7 of the 9 focal species (all species except dark-eyed junco and pygmy nuthatch).

At the level of the individual tree chosen as a nest site, most cavity nesters showed a strong preference for snags, using snags in greater proportion than expected based on available trees. However, except for the northern flicker, all cavity nesters used live trees for 42% (mountain chickadee, pygmy nuthatch) to 80% (white-breasted nuthatch) of their nests. The 2 cup-nesters (solitary vireo, western tanager) nested exclusively in live trees, with tanagers nesting almost exclusively in ponderosa pine. Although the solitary vireo nested in a broad range of tree sizes, the other 6 bird species showed a strong preference for nesting in the largest trees; this was true for both pines and oaks, live and snag.

At the level of the 20x20-m plot, species differed in their preferences for nest settings. Solitary vireos and white-breasted nuthatches selected habitats with more oak, perhaps reflecting their tendency to nest in oak trees. On the other hand, northern flickers, pygmy nuthatches, and western tanagers showed an aversion to oaks, especially small-diameter oaks. Despite the preference for large nest trees, few species showed any tendency to respond to the local density of large (>15" dbh) trees. The only 2 species that did (white-breasted nuthatch, mountain chickadees) seemed to prefer a wider than average spacing among large trees. Solitary vireos, white-breasted nuthatch, western bluebirds, and western tanagers seemed to prefer gentler slopes, and white-breasted nuthatches and western bluebirds both tended to pick nest locations with high canopy closure.

These findings may help interpret bird responses to the restoration treatments. For instance if western bluebirds were to decline with treatment, despite creation of what will certainly be more favorable foraging conditions, it may be due to their aversion to nesting in more open sites. We will also learn more about a species' habitat selection patterns by repeating these measurements after treatment. Perhaps many birds that are indifferent to (for example) canopy closure or spacing of large trees in the dense pre-treatment landscape will manifest selection with respect to

these habitat features in the more open post-treatment landscape.

Our methods are described in detail, and quantitative data summaries and analyses for the first 2 years (i.e., 1996 and 1997) are available on the web as noted below.

Table 1. Nests monitored on MTRCA study area, by species and year. We measured vegetation on a 20x20-m plot centered on each nest.

Species	Year			Total
	1996	1997	1998	
Dark-eyed junco	3	1	3	7
Hairy woodpecker	3	0	9	12
Mountain chickadee	3	9	22	34
Pygmy nuthatch	7	5	4	16
Solitary vireo	7	22	23	52
White-breasted nuthatch	8	16	22	46
Western bluebird	9	18	38	65
Western tanager	11	19	25	55

Table 2. Foraging observations on MTRCA study area, by species and year. We measured vegetation on a 20x20-m plot centered on each foraging observation. We did not make foraging observations in 1996.

Species	YEAR		Total
	1997	1998	
Dark-eyed junco	7	32	39
Hairy woodpecker	7	34	41
Mountain chickadee	24	40	64
Pygmy nuthatch	7	29	36
Solitary vireo	0	36	36
White-breasted nuthatch	24	41	65
Western tanager	1	37	38

Management recommendations: Recommendations will not be available until we have collected and analyzed post-treatment data. Following recommendations from BLM personnel in late 1995 and early 1996, I selected a treatment area that we all believed would be treated starting in late 1997. In fact this area has only begun to be treated in 2000.

Keywords: habitat selection, reproductive success, passerine birds, foraging habitat, nest site selection.

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Detailed methods, and data summaries for 1996 and 1997 (the first 2 of the 3 years) are available at http://www.for.nau.edu/~pb1/pipobird.html

Butterfly Response to Ecosystem Restoration

Principal Investigator, Collaborators and Assistants: Amy E.M. Waltz, W. Wallace Covington, Thomas Sisk, Jason Brooks, Liza Comita, Codey Carter, Walker Chancellor, Barbara Kent, Lisa Machina, Cecilia Meyer, Ted Ojeda, Holly Petrillo, Scott Schaff, Stacey Sprecher, Alex Viktora, Melanie Walker.

Funding: Restoration of Ecosystem Health in Southwest Forests, Department of Interior and Arizona Strip District BLM.

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Waltz, Amy E.M. and W. Wallace Covington. 1999. Butterfly richness and abundance increase in restored ponderosa pine ecosystem (Arizona). Ecological Restoration 17(4):244-246.

Waltz, Amy E.M. and W. Wallace Covington. 1998. Butterfly response to ponderosa pine restoration. Society for Ecological Restoration International Conference. September 28-30, 1998. Austin, TX.

Summary:

Butterflies are suggested to be potential indicators of arthropod communities, bird communities and even forest health. Because of this, we initiated butterfly monitoring in the Mt. Trumbull ecosystem area in 1997. Monitoring transects were established in the Lava Unit (96-1, treated 1996), and untreated forest adjacent to the Lava Unit, and in all 5 experimental blocks. Pre-treatment data were collected in the experimental blocks in 1997 and 1998. In 1999, transects were added in the newly treated Trick Tank (96-2) unit. This unit and the Lava unit have had continuing monitoring since their respective treatments. Monitoring in the experimental blocks was halted in 1999 due to on-going treatments. Post-treatment monitoring of both control and treatment within the experimental blocks commenced summer 2000.

Nectar availability was also assessed at the Mt. Trumbull treated (Lava and Trick Tank) units and their respective controls in 1998, 1999 and 2000. Initial results show much higher nectar resource in the treated units than in the control. During 2000, nectar was also assessed in the experimental blocks. This data has not yet been analyzed. In addition, host plant availability will be gathered from vegetation data collected in 1999 and 2000 from the experimental bocks and the two treated units.

Life history traits of the silver-spotted skipper (*Epargyreus clarus*) were also collected to predict the responses of this species to restoration treatments. The silver-spotted skipper hosts on New Mexican Locust which is a shrub/tree species that resprouts quickly after fire. Abundances of the skipper were sampled on mature locust, resprouted locust, and on locust in sun and shade to determine patterns. Preliminary data suggests skippers prefer host plants in the sun, but do not initially utilize the resprout.

In addition to the sampling at Mt. Trumbull, we monitored butterfly populations in remnant areas that might represent forests of presettlement time. Isolated plateaus of the north rim of Grand Canyon National Park, including Fire Point, Powell Plateau and Rainbow Plateau were

surveyed to assess butterfly communities in remnant old-growth forests. Butterfly guilds found in these areas may indicate what should be found in restored butterfly communities. These sites had additional species not found at Mt. Trumbull, most likely as a result of the more diverse understory found on these remote plateaus

Keywords: biodiversity, biodiversity indicators, herbivore-plant interactions, indicator species, Lepidoptera, silver-spotted skipper, succession.

Management recommendations: Butterflies do increase in openings created by thinning and burning associated with ponderosa pine restoration. Much of the increase is probably due to the early successional nectar resources commonly available after the initial restoration disturbance. However, the majority of species observed are local species (not migratory), indicating host-plant availability within the site, although the exact range differs with species. Unfortunately, there is not enough data to state whether seeding with native species affects the establishment of the butterfly community. Butterflies were common in both seeded and unseeded portions of the Lava Unit (96-1), although this is a limited sample. Most commonly used nectar plants were common groundsel, *Senecio multilobatus*, and fleabane, *Erigeron divergens*. Host plants of the most commonly observed species were legumes (lupines, loco weed, locust) and trees (oak). Wood nymph caterpillars host on grasses, and have only been seen in the Logan burn area adjacent south of the Nixon Administrative site, which was seeded with grasses. The establishment of these wood nymph butterflies in restoration treatment sites may suggest an adequate abundance of their host grass.

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Habitat relationships of the Kaibab squirrel and other sciurids

Principal Investigator, Collaborators and Assistants: Michael Elson, Wallace Covington, Pete Fulé, ERI staff and students.

Main Funding Source: Restoration of Ecosystem Health, BLM-Department of Interior.

Bibliography:

Elson, M. 1999. Tassel-eared squirrel foraging patterns and projected effects of ecological restoration treatments at Mt. Trumbull, Arizona. M.S. Thesis. Northern Arizona University.

Summary:

Tassel-eared squirrels (*Sciurus aberti*) are an important component of southwestern ponderosa pine (*Pinus pondersa*) ecosystems. Tassel-eared squirrel habitat has been altered by the interruption of the natural fire regime, which maintained low tree densities and diverse stand structures prior to Euro-American settlement. Although ecological restoration efforts seeking to restore presettlement conditions through mechanical thinning and prescribed fire are currently underway in many areas of the Southwest, the effects of restoration treatments on tassel-eared squirrels are unknown. We selected three experimental blocks at Mt. Trumbull, Arizona, to represent a continuum of stand types prior to ecological restoration. The locations of all tassel-eared squirrel feed trees were mapped in a total of 27 hectares. Data collected on each feed tree included tree status (leave or take), dbh, number of clipped needle clusters, number of peeled cone cores, number of fungi digs, relative abundance of old clipped clusters, tree damage, and the presettlement status of the tree. We determined the characteristics and spatial pattern of feed trees under current conditions at Mt. Trumbull and predicted changes due to restoration

treatments using the marked status of trees. The current prescription resulted in low percentages of the trees currently used for foraging on inner bark being marked for retention in the three treatment units surveyed. Trees selected by squirrels for foraging on ovulate cones were retained at higher percentages. More random spatial distribution and larger average sizes of retained feed trees are predicted. We predict corresponding reductions in squirrel foraging habitat. The individual tree approach is predicted to significantly reduce impacts on forage availability while having little impact on structural objectives of current prescriptions. It is uncertain, however, whether the available forage will be fully utilized. The patch approach is predicted to have greater benefits for squirrels and is considered a more reliable approach to mitigating impacts. Implementing the patch approach, however, would require fundamental changes in current objectives and marking guidelines—a cost which may outweigh the anticipated benefits.

Keywords: wildlife habitat, habitat use, spatial analysis

Management Recommendations: Because this research used pre-treatment data to predict changes in squirrel habitat, no recommendations can be made at this time. Ideally, more data would be collected, to assess the valid of predicted changes in feed tree availability.

Predicting the effects of ecosystem fragmentation and restoration: management models for animal populations

Principal Investigators, Collaborators, and Assistants: Thomas D. Sisk, Center for Environmental Sciences and Education, Northern Arizona University and Barry R. Noon, Department of Fishery and Wildlife Biology, Colorado State University.

Funding: Strategic Environmental Research and Development Program.

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Meyer, C. L. and T. D. Sisk. 2000. The response of microclimate and butterflies to structural edges in ponderosa pine forests (talk). Annual meeting of the Society for Conservation Biology. Missoula, MT.

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Summary:

This project is part of a larger study that encompasses both ponderosa pine forests and southwestern riparian ecosystems. It consists of three parts: 1) the development of a model of animal response to landscape change that explicitly incorporates animal responses to habitat edges, 2) an investigation of microclimatic gradients across habitat edges, and 3) an investigation of the population dynamics of mobile animals in landscapes that have undergone restoration treatments.

Part 1. Animal responses to habitat edges can be important determinants of habitat quality. Restoration creates a novel form of habitat edge—the edge between restored and unrestored forest habitats. In order to determine how animals respond to this edge, we conduct surveys of passerine birds and butterflies along transects running perpendicular to habitat edges. Data from these surveys are used to develop species-specific functions describing changes in animal abundance with relation to distance from the edge. We use these functions to parameterize a model of animal densities in the post-restoration landscape. The modeling approach will project the species-specific edge responses, measured in the field and characterized mathematically, onto spatially explicit habitat maps, weighting each habitat patch according to its area and the influence of the surrounding habitat on species abundance. Measurement, analysis of responses, and model-building will continue in FY01-02.

Part 2. Restoration of forest ecosystems results in altered stand structure, affecting microclimatic factors such as air temperature, light intensity, and relative humidity. These microclimatic changes alter moisture content of dead and down wood, site suitability for understory vegetation, and habitat quality for invertebrates and other forest organisms. At Mt. Trumbull, we have monitored microclimate before the restoration treatment with small, compact, portable data loggers. Collection of post-treatment data has been hampered by the slowed progress on restoration treatments, but our results to date indicate that, while there are consistent differences in light intensity across the edge, differences in humidity and temperature are, when present at all, restricted to relatively short periods during the day. This fundamental ecological information will be valuable in assessing the impacts of restoration on processes as varied as fuel conditions and fire behavior, wildlife habitat selection, and plant and animal reproductive success.

Part 3. Restoration creates a novel landscape in which animals are faced with a choice between restored and unrestored habitats. How animals respond to this landscape—how and how well they select habitats—will have a substantial impact on how restoration ultimately affects wildlife populations. To address the question of how animals respond to this novel landscape, we will use an iterative process of modeling and field work to study the population dynamics of two bird and two butterfly species inhabiting a landscape containing a mosaic of restored and unrestored forest. We will examine in detail the relationship between habitat selection and fitness in each species. This information will be used to create a generalized simulation model that can be parameterized with information on animal abundance and reproductive success and used to predict animal responses to landscape change associated with restoration. The model and response data generated by this project will provide a tool that will allow managers to assess the implications of different restoration scenarios for animal populations. Measurement, analysis , and model-building will continue in FY01-02.

Management Recommendations: As this project is still in progress, we have not yet developed specific management recommendations.

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Response of small mammal communities and Sin Nombre virus to ecological restoration of ponderosa pine in northern Arizona

Principal Investigators, Collaborators, and Assistants: Carol L. Chambers, Heather Shanes, Victor Alm, Chris Davis, Lisa Gelcsiz, Tianna Kennedy, AJ Montatesti, Jamie Moser, Jenni Neagel, Chad Newberry, Rich Reading, Joe Renaldi, Justin Waskiewicz, Fenner Yarborough, and Nathan Zorich.

Funding: Restoration of Ecosystem Health in Southwest Forests, Department of Interior and Arizona Strip District BLM.

Bibliography:

Papers:

Chambers, C.L. Forest Management and the Dead Wood Resource in Ponderosa Pine Forests: Effects on Vertebrates. Symposium on the Ecology and Management of Dead Wood in Western Forests, November 2-4, 1999, Reno, NV (Accepted).

Presentations:

Chambers, C.L. Arizona/New Mexico Chapters of The Wildlife Society 33rd Joint Annual Meeting (February 2000), Speaker, *Forest Management and the Dead Wood Resource in Ponderosa Pine Forests: Effects on Vertebrates*

Chambers, C.L. Symposium on the Ecology and Management of Dead Wood in Western Forests (November 1999), Speaker, *Ecological Restoration and the Dead Wood Resource in Ponderosa Pine Forests: Effects on Vertebrates*

Chambers, C.L. Arizona/New Mexico Chapters of The Wildlife Society 32nd Joint Annual Meeting (February 1999), Speaker, *Developing Forest Restoration Plans to Include Wildlife Objectives*

Chambers, C.L. The Wildlife Society 5th Annual Conference (September 1998), Invited Speaker, *Setting Restoration Objectives for Wildlife: What do we need to know?*

Shanes, Heather A., Carol L. Chambers, Ken D. Abbott, W. Wallace Covington. Hantavirus in rodent populations of ponderosa pine forest restoration sites. Abstract for Southwest Chapter of the National Wildlife Society meeting in February 1999

Shanes, Heather A., Carol L. Chambers, Ken D. Abbott, W. Wallace Covington,. Hantavirus in rodent populations of ponderosa pine forest restoration sites. Abstract for Steps Toward Stewardship: Ponderosa Pine Ecosystems Restoration and Conservation Conference in April 2000 (Poster)

Shanes, Heather A., Carol L. Chambers, Ken D. Abbott, W. Wallace Covington. Hantavirus in rodent populations of ponderosa pine forest restoration sites. Abstract for Society for Ecological Restoration national conference in San Francisco, CA, September 1999 (Poster)

Summary:

1998

Small mammal live-trapping was conducted on five EB units. A 10x10 trapping grid was established on the control and treatment stands of each unit. Grid points were spaced 20 meters apart and were laid over the permanent vegetation sampling points. Grid design was slightly modified in EB-1 control, EB-2 treatment, and EB-4 treatment stands in order to compensate for stand size and boundary markings. Permanent vegetation sampling points were also utilized for grid lay out in these stands.

Trapping was conducted for 5 days on each EB unit. A total of approximately 311 individuals were captured during the trapping period. The species of small mammals captured were cliff chipmunk (*Tamias dorsalis*), deer mouse *(Peromyscus maniculatus*), brush mouse (P. *boylii*), and pinyon mouse (*P. truei*). Standard measurements, weight, and reproductive condition of each animal were obtained using established methodologies. A blood sample was collected from each individual, with the exception of juveniles under 8.0 grams, birthing females, and animals that had experienced weather-related trauma. Approximately 286 blood samples were sent to the CDC for hantavirus testing.

Results of 1998 blood sampling revealed that hantavirus was most prevalent in brush mice (17.3%), less prevalent in pinyon mice (10.4%), and least prevalent in deer mice (4.7%). We found more antibody-positive male brush mice than females. We did not detect significant differences in the sex ratios of antibody-positive pinyon mice and deer mice. Our findings regarding brush mice were consistent with previous studies. However, blood-sampling results from pinyon mice and deer mice may indicate inconsistencies with other findings. Based on previous studies, we expected to find more antibody-positive males than females in all species. Hantavirus levels in rodents at Mt. Trumbull were slightly higher than in rodents at other sites in northern Arizona (Camp Navajo and Grand Canyon South Rim).

1999

In 1999, we included methods to investigate the spread of hantavirus through rodent populations over time. We trapped EB units 1 and 2 for a period of 4 consecutive nights during May, June, and July. We trapped the EB-3 unit during the May and June trapping sessions, but were not able to trap there in July because restoration treatments were being applied. (We excluded EB units 4 and 5 because treatments had not been applied.) We measured microhabitat characteristics (trees, shrubs, snags, logs, herbaceous species, canopy cover, and litter depths within a 5 meter radius of each trap) during June and July.

We captured approximately 213 individuals representing 5 species during 5900 trap nights. Small mammals captured included deer mouse (121 individuals), brush mouse (48 individuals), pinyon mouse (14 individuals), cliff chipmunk (*Tamias dorsalis*; 28 individuals), and harvest mouse (*Reithrodontomys megalotis*; 2 individuals). For each animal we measured standard characteristics, weight, and noted reproductive condition and age class. We collected a blood sample from each animal in good condition, excluding juveniles under 8.0 grams and birthing females. We also excluded cliff chipmunks, as they do not typically carry hantavirus.

We sent 178 blood samples to the Centers for Disease Control and Prevention (CDC) for hantavirus testing. May blood sampling results revealed that 20.0% of brush mice and 11.1% of deer mice tested positive to hantavirus antibodies. No pinyon mice or harvest mice tested antibody-positive. June results revealed that 25.0% of brush mice, 4.0% of deer mice, and 10.0% of pinyon mice tested antibody-positive. In July, 13.3% of brush mice tested antibody-positive.

No deer mice, pinyon mice, or harvest mice were antibody-positive. Viral levels in rodent populations appear lower than in July 1998. However, the antibody-positive deer mice captured in June occurred on EB 3T, which was not trapped in July due to thinning operations. Additionally, the 1 antibody-positive pinyon mouse captured in June was not recaptured in July.

2000

In 2000, we trapped EB units 1-3 during May, June, and July following 1999 methods. Additionally, we trapped the new EB-3 control and EB-4 for 4 consecutive days in July. We collected microhabitat data during June and July on EB units 1-3.

We captured approximately 247 individuals representing 6 species during 6965 trap nights, from EB units 1-3. Small mammals captured included deer mouse (174 individuals), brush mouse (54 individuals), pinyon mouse (11 individuals), cliff chipmunk (23 individuals), and harvest mouse (1 individual). We captured 1 deer mouse from the new EB-3 control. Results from EB-4 trapping can be obtained from Dr. Chambers.

We sent 134 blood samples to the CDC for hantavirus testing. May blood sampling results revealed that 7.1% of brush mice tested positive to hantavirus antibodies. No deer mice or pinyon mice tested antibody-positive. June results revealed that 5.9% of brush mice and 3.6% of deer mice tested antibody-positive. No pinyon mice were antibody-positive. We have not received blood-sampling results from July.

We are currently entering microhabitat data and will be conducting analysis through December.

Keywords: hantavirus, *Peromyscus boylii*, *Peromyscus maniculatus*, *Peromyscus truei*.

Utilization and Significance of Downed Wood as Habitat for Two Species of Mice (Peromyscus spp.) in a Restored and a Control Stand of Ponderosa Pine Forest in N. Arizona

Principle Investigators: Carol L. Chambers, Pete Fulé

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Ecological Restoration Institute Research Assistants: Shawn Knox, Justin Waskiewicz, Daniel Murray, and Matt Hurteau

Funding: Resotoration of Ecosystem Health, BLM, Department of Interior.

Summary:

We monitored movements and habitat use of small mammals (*Peromyscus sp.*) in the Mt. Trumbull EB-4 Unit for ten days in July 2000. Trapping occurred in conjunction with the Hantavirus study being conducted by Dr. Chambers and Graduate Research Assistant Heather Shanes. The small mammals were first captured to test for levels of Hantavirus. Data was also taken on morphological characteristics, weight, reproductive condition, and age class. Blood samples were sent to the Center for Disease Control and Prevention (CDC) for testing; results have not yet been received.

Only two species of mice were captured in the initial trapping session in unit EB-4 (using 200 Sherman live-traps, for a period of 3 consecutive nights in July), as follows: 12 individual deer mice (*Peromyscus maniculatus*) were captured in the treatment site; and eight individual pinyon mice (*Peromyscus truei*) were captured in the Control site. One cliff chipmunk (*Tamias dorsalis)*

was captured in the treatment, and released. As the animals were recaptured during the same trapping session, 15 adult mice (10 deer mice and 5 pinyon mice) were fitted with radio transmitter collars and re-released at their point of capture. After ten days of tracking their movements, a second trapping session (4 nights) was initiated to recapture the animals and remove the collars.

We measured microhabitat characteristics (logs, trees, shrubs, snags, herbaceous species, canopy cover, and litter depths within a 5 meter radius of each day nest site, and of random sites) during August 2000.

Preliminary results seem to show that the deer mice are utilizing "stump holes" (root holes which remain after snags have been completely consumed by fire) for nest sites, while pinyon mice used large diameter (>50 cm) presettlement ponderosa pine logs and cavities in live presettlement juniper trees. Pinyon mice were the dominant species found in EB-4 Treatment prior to treatment. Changes in forest structure and composition, resulting from the treatment, appeared to greatly reduce habitat for pinyon mice.

Management recommendations: Maintaining large-diameter (presettlement) logs, stumps, and snags may be important in maintaining a diverse population of native small mammal species.

Upcoming Goals:

We will complete data entry and preliminary analyses by January 2001. We intend to revisit EB 4 in 2001 to retrap the sites, resample hantavirus levels, and remeasure habitat characteristics in order to examine second year post-treatment changes in the small mammal communities.

COLLABORATIVE EFFORTS

Mt. Trumbull Collaboration

This project has been marked as a model of cooperation and collaboration for multi-agency efforts. The cooperation of the Arizona Game and Fish Department (AzG&F), Northern Arizona University (NAU), and the Bureau of Land Management (BLM) has been outstanding and is often cited as example for these types of projects.

The BLM has adjusted the on-the-ground management several times to accommodate the needs of research by both NAU and Az. G&F. This adjustment has included working with the permittees to adjust grazing schedules, adjustment of burning windows, rescheduling district work in archeology, forest management, road maintenance, building maintenance, fuels reduction and fire management. In addition they have been very accommodating in schedules of meetings, driving frequently to Flagstaff, assisting in the development of research schedules and designs, working with NAU and Az. G&F to get funding, and providing support to research.

There have been at least three **MAJOR** instances of BLM adjustments to work schedules of BLM crews to provide for research needs. These include contracting of thinning during the winter of 1999-2000, fire crew deployment in 1998, and beefing up of the fuels crew in 2000. These efforts were a large disruption of the BLM schedule but were done anyway after the needs of research were expressed.

NAU and Az. G&F have participated in tours for BLM, lectures for education and many

meetings with BLM to explain the project and findings.

A strong spirit of "being in this together" exists for this project. There is more use of the pronoun "we" than of the pronoun "they". Rarely is an action taken without consultation of the partners.

Mt. Trumbull Wilderness Restoration Collaboration

The Arizona Strip District of the BLM has long been concerned with the condition of the forest stand on the top of Mt. Trumbull, designated wilderness since 1984. Although never logged, the stand on Mt. Trumbull was grazed enough to stop fires, followed by a tree irruption and loss of herbaceous abundance that is typical of ponderosa pine forests found across the southwest. Current stands are dense, and the remaining old-growth trees are declining due to stress from competition with the younger trees. Fuel loadings are much higher than in Pre-European settlement times, and include a living fuel ladder that would easily move wildfire into crowns of old-growth trees. Initial observation reveals the herbaceous layer is composed primarily of natives, with little invasion of exotic species, however overall abundance of the grasses and forbs are low. With living Pre-European settlement trees and a mostly native understory, the Mt. Trumbull wilderness would respond well to restoration efforts.

In the spring of 1999, BLM managers initiated discussions on restoration treatments in wilderness areas. Although fire is a commonly used and accepted management tool in wilderness areas, the thinning of trees in wilderness areas is highly contested. The managers at the BLM agreed to a collaborative effort involving land managers, scientists, and members of the environmental community to decide if treatment is necessary in the Mt. Trumbull wilderness, and if so, what kinds of treatments are necessary.

On November 9th & 10th, 1999 approximately 50 people representing local and national environmental organizations, local citizens, land management agencies and scientists gathered at Mt. Trumbull to determine whether or not to proceed with a discussion about wilderness restoration. A steering committee was formed and met in July of 2000 to establish a timeline for the discussion. The goal of the process is to develop alternatives for wilderness restoration and to select a preferred alternative by October of 2001. The next meeting for the general public is scheduled for November 2nd and 3rd, 2000 in Flagstaff, AZ.

OUTREACH

Providing information to other land managers and the general public is an important part of this joint restoration project. Environmental groups, land managers, the general public, and service organizations have continued to express a large amount of interest in the Mt. Trumbull project. Presentations have ranged from slide shows to on site tours, and have been greeted with great enthusiasm. Several occasions provided the Mt. Trumbull project with collaborative opportunities. In May, Joe Feller of the ASU faculty brought his law class to see the restoration work and to hear about the background and changes in the ecosystem. NAU-School of Forestry participated, along with BLM range and project personnel. In mid-June, we had an on-site collaborative session between the land managers, researchers, game managers, ranchers, loggers, and local residents. This session helped to identify concerns of all melded into one action plan.

The next day gave the researchers and managers an opportunity forecast activities on the Mt. Trumbull area. There were other opportunities to showcase the restoration such as the Mt. Emma fire where the prescribed natural fire folks such as Tom Zimmerman, Ph.D, Alan Farnsworth, and others got a first hand look at the restoration. Another opportunity allowed Senator Kyl and the staff of Senator McCain to visit the area and be involved in discussions with researchers and managers about the restoration efforts. They were able to see results of the thinning and reintroduction of prescribed fire. As more data is analyzed and more findings become apparent, NAU and the Arizona Strip District will continue to provide that information.

CONTRIBUTORS

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SPECIAL THANKS

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PRESENTATIONS AND PAPERS

PRESENTATIONS

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Chambers, C.L. Symposium on the Ecology and Management of Dead Wood in Western Forests (November 1999), Speaker, *Ecological Restoration and the Dead Wood Resource in Ponderosa Pine Forests: Effects on Vertebrates*

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Lesh, T. D. 1999. Selection of foraging habitat by passerine birds in pine-oak forests. Oral presentation at Arizona-New Mexico meetings of The Wildlife Society, February 1999.

Meyer, C. L. and T. D. Sisk. 1999. The response of Colias eurytheme (Lepidoptera:Pieris) and Neophasia menapia (Lepidoptera:Pieris) to the structural edge created by Ponderosa Pine restoration in Northern Arizona (talk). Fifth biennial conference of research on the Colorado Plateau. Flagstaff, AZ.

Restoration of ponderosa pine ecosystems results in altered stand structure, potentially altering habitat suitability for invertebrates and other forest organisms. This research focused on determining the response of two butterfly species, Colias eurytheme and Neophasia menapia, to the structural edge created by restoration activities in ponderosa pine forest. About fifty individuals of each species were collected and placed at east- and west-facing edges before dawn. The time of initial flight, initial flight direction, and each individual's edge avoidance response were recorded. Butterflies of both species that were placed at the east-facing edge flew earlier than butterflies placed at the west-facing edge, indicating that the microclimate at the east-facing edge was more favorable for flight. Light intensity was stronger and temperatures were higher earlier at the east-facing edge. Colias eurytheme typically avoided the structural edge during its initial flight, while Neophasia menapia did not. This was consistent with expectations, because Colias eurytheme shows a preference for open areas, while Neophasia menapia shows a preference for ponderosa pine forest. These results indicate that forest restoration affects microclimate, influencing animal behavior, and they suggest that butterflies may be able to perceive structural changes in the habitat surrounding them and make movement decisions based on their perceptions.

Meyer, C. L. and T. D. Sisk. 2000. The response of microclimate and butterflies to structural edges in ponderosa pine forests (talk). Annual meeting of the Society for Conservation Biology. Missoula, MT.

Efforts to restore ponderosa pine ecosystems to conditions that predominated prior to European settlement result in altered stand structures, potentially affecting habitat suitability for invertebrates and other forest organisms. We measured the microclimatic gradient across the structural edge created by restoration treatments, as well as the responses of two

butterfly species, Colias eurytheme and Neophasia menapia, to structural and microclimatic factors. Light intensity, air temperature, and relative humidity were measured across east- and west-facing edges. The microclimatic edge gradient showed weak and variable patterns during midday, however, we observed significant differences during the morning hours, with increased light intensity and temperature at the east-facing edge. Adult butterflies, released before dawn, flew earlier at the east-facing edge than at the west facing edge, and they more often flew away from the edge into the restored forest. Our results indicate that restoration treatments in ponderosa pine forests have moderate effects on forest microclimates, but that these effects may significantly influence adult butterfly behavior. Planning for forest restoration treatments should consider the effects of landscape structure on microclimate, which has the potential to influence the distribution and local abundance of insect herbivores and pollinators.

Roccaforte, John Paul, W. Wallace Covington, Margaret M. Moore, Hiram B. Smith, Amy E.M. Waltz, and Thomas A. Heinlein. Applied Restoration Research and Management in Southwestern Forest Ecosystems (poster). Society for Ecological Restoration Annual Meeting, September 1999, San Francisco, CA.

Forest ecosystems throughout the southwestern United States have become overly dense with trees and structurally homogeneous as a result of livestock grazing, logging, and fire suppression. In addition, native herbaceous communities have become less diverse and abundant as forest fuels steadily accumulate. These simplified ecosystems are more vulnerable to the effects of catastrophic wild fire. Over the past seven years, the Ecological Restoration Institute at Northern Arizona University has initiated twelve restoration-based research projects in cooperation with environmental organizations, private landowners, Native American tribes and public land management agencies throughout Arizona and New Mexico; and incorporated the diverse goals of these groups. The goals of this research are to document contemporary ecological trends, determine reference conditions, and develop restoration techniques based on an adaptive management model. Restoration techniques focus on tree thinning to emulate presettlement spatial patterns, the reintroduction of frequent, low-intensity fires, and the restoration of native herbaceous communities. This poster presents an overview of the background and progress of each project.

Shanes, Heather A., Carol L. Chambers, Ken D. Abbott, W. Wallace Covington. Hantavirus in rodent populations of ponderosa pine forest restoration sites. Abstract for Southwest Chapter of the National Wildlife Society meeting in February 1999

In 1993, an outbreak of human respiratory distress syndrome occurred in the Four Corners area of the southwest. The infectious agent was determined to be a hantavirus transmitted to humans by rodent vectors in the genus *Peromyscus*. Although studies have been conducted in many habitat types in Arizona (e.g., pinyon pine-juniper, Sonoran desert), few studies of rodent host populations have been conducted in ponderosa pine forests of northern Arizona. No studies have attempted to determine effects of forest restoration treatments (thinning and prescribed burning) on small mammals or hantavirus. The objectives of this study were to obtain baseline data on small mammal population densities in ponderosa pine forest sites prior to restoration and to determine levels of hantavirus within those rodent populations. We established 20 experimental stands at 3 sites: Mt. Trumbull (10 stands), Camp Navajo (6 stands), and Grand Canyon National Park (4 stands). Each stand was trapped using a 10x10 grid on 20-m spacing (100 Sherman live traps). Trapping was conducted for 4-5 consecutive days (until recapture rate exceeded 80%). Blood samples were drawn from all animals on the first capture. Samples were tested for hantavirus by the Center for Disease Control. We captured 854 individuals representing 6 species during 8000 trap nights. Species included *Peromyscus maniculatus* (72.0% of all animals

captured), *Peromyscus boylii* (11.2% of animals captured), *Peromyscus truei* (8.9% of animals captured), *Neotoma stephensi* (3.7% of animals captured), *Eutamias cinereicollis* (2.3% of all animals captured), and *Tamias dorsalis* (1.9% of animals captured). To date we have received blood sample results from rodents captured at Mt. Trumbull. Hantavirus was determined to be most prevalent in *P. boylii* (17.3%), less prevalent in *P. truei* (10.4%), *P. maniculatus* (4.7%), and absent in *T. dorsalis* (0%). We found more seropositive male *P. boylii* than females. We did not detect significant differences in the sex ratios of seropositive *P. truei* and *P. maniculatus*. Our findings regarding *P. boylii* were consistent with previous studies. However, the results of our study regarding *P. truei* and *P. maniculatus* may indicate inconsistencies with other findings. Based on previous studies, we expected to find more seropositive males than females in all species. Further investigation is necessary to determine the effects of forest restoration treatments on hantavirus levels within small mammal communities.

Shanes, Heather A., Carol L. Chambers, Ken D. Abbott, W. Wallace Covington. Hantavirus in rodent populations of ponderosa pine forest restoration sites. Abstract for Society for Ecological Restoration national conference in San Francisco, CA, September 1999 (Poster)

In 1993, an outbreak of human respiratory distress syndrome occurred in the Four Corners area of the southwest. The infectious agent was determined to be a hantavirus (Sin Nombre virus, SNV) transmitted to humans by rodent vectors. The primary rodent host of SNV, the deer mouse, commonly occurs in ponderosa pine forests. No studies have attempted to determine the effects of forest restoration treatments (thinning and prescribed burning) on rodent/hantavirus associations. Our objectives were to describe small mammal population densities in ponderosa pine forests prior to restoration and determine levels of hantavirus. We established experimental stands at 3 sites in northern Arizona. Trapping was conducted for 4 to 5 consecutive days. Blood samples were drawn from animals on the first capture. Samples were tested for IgG antibody to SNV by the Centers for Disease Control (CDC). We captured 854 individuals representing 6 species during 8000 trap nights. Species included deer mice (72.0% of animals captured), brush mice (11.2%), pinyon mice (8.9%), Stephen's woodrats (3.7%), gray-collared chipmunks (2.3%), and cliff chipmunks (1.9%). SNV antibody-prevalence was brush mice, lower in pinyon mice and deer mice, and absent in Stephen's woodrats and cliff chipmunks. Further research is necessary to determine the effects of forest restoration treatments on rodent host/hantavirus associations, population dynamics, and prevention measures for human hantavirus disease.

Shanes, Heather A., Carol L. Chambers, Ken D. Abbott, W. Wallace Covington,. Hantavirus in rodent populations of ponderosa pine forest restoration sites. Abstract for Steps Toward Stewardship: Ponderosa Pine Ecosystems Restoration and Conservation Conference in April 2000 (Poster)

In 1993, an outbreak of human respiratory distress syndrome occurred in the Four Corners area of the southwest. The infectious agent was determined to be a hantavirus (Sin Nombre virus, SNV) transmitted to humans by rodent vectors. The primary rodent host of SNV, the deer mouse, commonly occurs in ponderosa pine forests. No studies have attempted to determine the effects of forest restoration treatments (thinning and prescribed burning) on rodent/hantavirus associations. Our objectives were to describe small mammal population densities in ponderosa pine forests prior to restoration and determine levels of hantavirus. We established experimental stands at 3 sites in northern Arizona. Trapping was conducted for 4 to 5 consecutive days. Blood samples were drawn from animals on the first capture. Samples were tested for IgG antibody to SNV by the Centers for Disease Control and Prevention (CDC). We captured 854 individuals representing 6 species during 8000 trap nights. Species included deer mice (72.0% of animals captured),

brush mice (11.2%), pinyon mice (8.9%), gray-collared chipmunks (2.3%), and cliff chipmunks (1.9%). SNV antibody-prevalence was greatest in brush mice, lower in pinyon mice and deer mice, and absent in Stephen's woodrats and chipmunks. Further research is necessary to determine the effects of forest restoration treatments on rodent host/hantavirus associations, population dynamics, and prevention measures for human hantavirus disease.

Waltz, Amy E.M. and W. Wallace Covington. 1998. Butterfly Response to Ponderosa Pine Restoration. Society for Ecological Restoration, September 1998, Austin, TX.

Butterflies can be an important indicator of forest health as well as ecosystem change. We monitored changes in butterfly abundance at the Mt. Trumbull ponderosa pine restoration project, in northern Arizona. At this site, the ponderosa pine and Gambel oak overstory were thinned to tree density levels at the time of Euro-American settlement. Following thinning, a low intensity fire was reintroduced to the system. Butterfly monitoring transects in untreated and treated areas were sampled from mid-May through August at two-week intervals in 1997 and 1998. Herbaceous communities along transects were surveyed in August of both years. Preliminary results of butterfly community structure in untreated and restored areas are presented here. Initial data show 25-30 diurnal Lepidoptera species in the area. We hypothesize that over time, 1. herbaceous production will increase in treated areas, and 2. this increase in nectar and larval food resources will result in increased diurnal butterfly abundance and diversity in the treated areas. However, 1 and 2 year responses to restoration (presented here) may show no change or decreases in diurnal Lepidoptera, as the herbaceous community can require up to five years for adequate reestablishment.

Waltz, Amy E.M., Peter Z. Fulé, W. Wallace Covington. 1999. Experimental restoration at the Mt. Trumbull Resource Conservation Area, Arizona (poster). Society for Ecological Restoration International Conference. September 23 – 25, 1999. San Francisco, CA.

The largest operational restoration site is restoring southwestern ponderosa pine forests to their pre Euro-American settlement conditions: open forest stands dominated by large, old trees above a rich, diverse understory of native grasses and wildflowers. In cooperation with Northern Arizona University (NAU) and the Arizona Game and Fish Department, the Arizona Strip District of the BLM has undertaken adaptive ecosystem restoration of southwestern ponderosa pine forests on a 3,000 acre area of the Mt. Trumbull Resource Conservation Area.

This project combines forest and ecosystem population monitoring on large, 1,000 acre parcels with a smaller scale, rigorous experimental design. Replication of ecosystem experimentation at landscape levels is difficult due to the amount of area needed, variation between sites, and the difficulty in establishing a homogenous control. To address these issues, researchers and land managers from Northern Arizona University and the Bureau of Land Management have designed a Randomized Complete Block Design to test the effects of restoration on ponderosa pine forest ecosystems. Five experimental blocks were established within the restoration project that represent the diversity of topography, elevation and forest type found in the area. Each block was divided into two similar units (each at least 25 acres), which were randomly assigned either control or restoration treatment.

Ecosystem variables, including forest and understory communities are measured at both scales; butterfly communities, edge effects on bird and butterfly communities, abiotic data, and small mammal communities, are measured at the smaller, experimental scale; and bird communities, deer populations and lizard communities are studied at the larger scale. This combination of large landscape studies with a rigorous, paired block experimental design can provide valuable information on the effects of restoration on different ecosystem variables.

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